FINAL PROJECT REPORT

Victorian Coastal Hazard Assessment 2017

Technical Report 1

A second-pass statewide assessment of erosion and inundation hazards resulting from future climate change scenarios to inform the Victorian Coastal Monitoring Program

Prepared for Department of Environment, Land, Water and Planning (DELWP)

Report 1 of 6

+61 9691 3000 | www.spatialvision.com.au | Level 8, 575 Bourke St, Melbourne 3000

About this Document

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Contact Person	Stephen Farrell
Telephone	(03) 9691 3028 / 0419 185 452
Email	Stephen.Farrell@spatialvision.com.au

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	Author	**Date**	**Signature**
Prepared by	Stephen Farrell	20/12/17	
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PART 1 - BACKGROUND

1. Document Purpose

This report presents the findings of a study undertaken to assess the likely impact of climate change on assets along the Victorian Coast. The report outlines the approach applied including the concepts and rationale, key terms and definitions, in addition to the key inputs.

The approach outlined was underpinned by a range of agreed spatial datasets that delineate each of the key inputs to the process. This approach presented has been applied to priority assets identified in earlier studies by the Department of Environment, Land, Water and Planning (DELWP), and other stakeholders, and the results of this assessment are included in this report.

This report has been prepared as part of the Victorian Coastal Hazard Assessment 2017 Project. This project involves a second-pass state-wide assessment of erosion and inundation hazards resulting from future climate change scenarios to inform the Victorian Coastal Monitoring Program. The project was undertaken to provide communities with information on coastal condition, change, hazards, and the expected impacts associated with climate change that will facilitate evidence-based decision making.

2. This Study

2.1 Background

DELWP requested the support of Spatial Vision with an assessment of the likely impacts of anticipated climate change on the Victorian Coastline.

This study was required to support development of a climate change risk assessment for the Victorian coast that built on earlier DELWP Risk Assessment work. Hence, in addition to providing a comprehensive review of the likely impact of climate change on the Victorian coast, the study was to consider the likely impact on coastal assets, and was required to incorporate a review of findings in relation to the 17 priority assets[1] identified and assessed in relation to risk in each of the DELWP regions.

The approach developed and applied in this project was required to draw on and be consistent with the CoastAdapt risk assessment approach. The study also drew on the approach applied by Spatial Vision in assessing the likely impact of anticipated climate change on natural assets. This study was undertaken in 2014 for 8 Victorian Catchment Management Authorities (CMAs).

Importantly, this assessment of the likely impacts of anticipated climate change on the Victorian Coastline involved undertaking a comprehensive spatially based impact assessment that considers multiple Victorian coastal assets. The assessment includes the use of currently available coastal biophysical data, assets and research findings.

This climate change risk assessment for the Victorian coast was required to support the Victorian Coastal Monitoring Program (VCMP) that aims to provide communities with information on coastal condition, change, hazards, and the expected impacts associated with climate change that will facilitate evidence-based decision making (i.e. invest in protection and intervention, or adaptation, or tolerate).

[1] Coastal Climate Change Risk Assessments (Volume 1 & 2), DELWP (2015)

The VCMP aims to develop:

1. Frameworks that consider present day and future risks of erosion, inundation stability and physico-chemical variation to natural coastlines and engineered structures that will inform prioritisation of coastal monitoring.
2. Partnerships with community groups (citizen science) and institutions to co-invest in coastal monitoring projects at both regional and local scales.
3. Data management infrastructure and decision support tools (where necessary) for coastal monitoring data that will inform:
   - Evaluation and application of policy, planning and climate adaptation instruments,
   - Investment and maintenance decisions for coastal protection structures, and
   - Reporting requirements for various purposes (eg State of the Coasts reporting).

2.2 Project Objectives

The primary objective of this study was to identify areas along coastal Victoria that will be most impacted by climate change in addition to areas where these impacts will significantly affect important coastal assets as identified by DELWP, amongst others.

The focus of this project was to develop a suitable spatial methodology that could be used to depict the likely areas impacted by anticipated climate change and to quantify the level to which coastal assets were likely to be impacted. An assessment of both impact and vulnerability were to be explored. The outputs of this work were to provide a spatial representation of coastal assets assessed to be at risk from climate change, and support the assignment of impact, vulnerability, and risk ratings to these assets.

Analysis of available coastal data highlighted areas of higher potential impact from climate change through an assessment of the exposure and sensitivity of natural and man-made assets to projected future changes in climate. The assessment included climate change projection scenarios for a range of time based projections to support planning and implementation of adaptation and mitigation activities.

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2.3 Key Deliverables

Key deliverables for the project were;

- An agreed coastal climate change impact assessment framework and approach with worked examples.
- A draft and final spatial climate change impact assessment for the Victorian coast, based on available biophysical data and expert opinion.
- A suite of spatial datasets that represent the key study findings, and selected study inputs.
- Implementation and incorporation of study outputs into the Coast Adapt web-resources tool to ensure study findings are made broadly available and can be further refined over time.

3. Key Project Considerations

3.1 Climate Change Impact Assessment Framework

This study drew on elements of the risk assessment framework developed by NCCARF. In relation to its consideration of coastal erosion impacts it also incorporated elements of the overall vulnerability assessment method, as outlined and adopted in the: *Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012; Local Government Association of South Australia*. This method describes how likely exposure to climate scenarios, and sensitivity and adaptive capacity of assets to these climate changes, are used to assess the likely impact and vulnerability of assets to these changes.

The CoastAdapt web-site also provided information, guidance and support on coastal impact and risk assessment approaches in addition to adaptation support material.

3.2 Climate Futures - Erosion and Inundation

A key requirement of this impact assessment was to determine the likely exposure over time to particular hazards, such as significant storm events and sea level rise.

In reference to climate change, many of the hazards to which the coast and coastal assets will be exposed were viewed as indirect, rather than direct, climate change stressors. The two key hazards identified in numerous studies and on the CoastAdapt web-site to which the Victorian coast, and coastal assets, will be exposed are:

- Erosion
- Inundation

Both erosion and inundation are natural processes along coastal areas. The principal rationale in undertaking the proposed framework was to assess the inherent sensitivities of coastal areas to these hazards and determine the potential impacts over time and under projected climate change scenarios.

The relationship between indirect stressors and the two major coastal hazards is presented in Table 1. This table shows how the same stressor (or exposure to that stressor) can generate both coastal erosion and inundation.

Table 1. Relationship between Hazards and Exposure

	Exposure to Stressors					
Hazard	Atmospheric	Storms	Sea Level	Waves	Sediment	Vertical Land Movement
Erosion	●	●	●	●	●	●
Inundation		●	●	●	●	

Climate change, as a driver of change in exposure to hazards, is expected to affect coastal asset types in different ways. A diagrammatic representation of these relationships is presented in Figure 1. Of primary concern are rising sea levels driven by multiple factors, such as melting ice caps and increasing water load in oceans. This will affect both erosion and inundation hazards to coastal assets. Climate changes are also noted to alter atmospheric conditions, such as wind direction and speed, precipitation frequency and total, altered temperatures, and indirectly – currents due to wind factors. Also related to climate change are increasing or altered storm frequency and severity, wave movement and severity, sediment transportation and deposition and vertical land movement, and relations to groundwater table recharge and use.

Vegetation cover can influence the impact these hazards have on coastal assets. Hence, temperature, along with rainfall could be considered in the context of its impact on vegetative cover. Temperature is also known to also influence water temperature.

Sea Level Rise and Storm Surge

Anticipated Sea Level Rise (SLR) and Storm Surge (STM) information is currently available for the Victorian Coastline for three dates based on a baseline of 2009. These were: 2040, 2070 and 2100. The relationship between the likely coastal changes for these periods and the anticipated global climate change and carbon emissions is not clear. Hence, for this study sea level rise and storm surge information was applied without reference to the Global Climate Change Models and their applied Recommended Concentration Pathways (eg. RCP 4.5 or RCP 8.5) emission scenario outputs.

Using a conservative approach, anticipated SLR and STM information was generally assumed to relate to the three climate timeframes as outlined in Table 2.

Table 2. Sea Level Rise and Storm Surge relationship with climate future years

Year for which Anticipated Sea Level Rise (SLR) and Storm Surge (STM) information was attributed	Anticipated Sea Level Rise (SLR)
2009	0cm
2040	20cm
2070	47cm
2100	82cm

Intense Weather Events

Climate changes will have an impact on indirect climate stressors such as flood frequency and intensity. This project applied 1 in 100 year flood information as an indicator of extreme flooding events.

While climate changes will have an impact on other indirect climate stressors, such as increased frequency of extreme events like storms, exposure surfaces or surrogate information related to these events was generally not available or in a suitable format for use in this project. Hence, wave energy, height and other coastline parameters were used to assess likely exposure to severe storm events.

Other Considerations

Also of consequence to the coastal strip and coastal assets was the presence of Coastal Acid Sulphate Soils (CASS). These soils naturally contain metal sulphide minerals. If these soils were disturbed through excavation, wetting events and exposure to air, they react with oxygen and produce sulfuric acid. This can be detrimental to the areas in which they are found as it can lead to acidification of water sources and soil profiles, breakdown of rocks, sediments and concrete and corrosion of metals.

In relation to this project, expert opinion was that CASS in the soil profile could become “activated” if exposed to storm surge events or extreme flooding events.

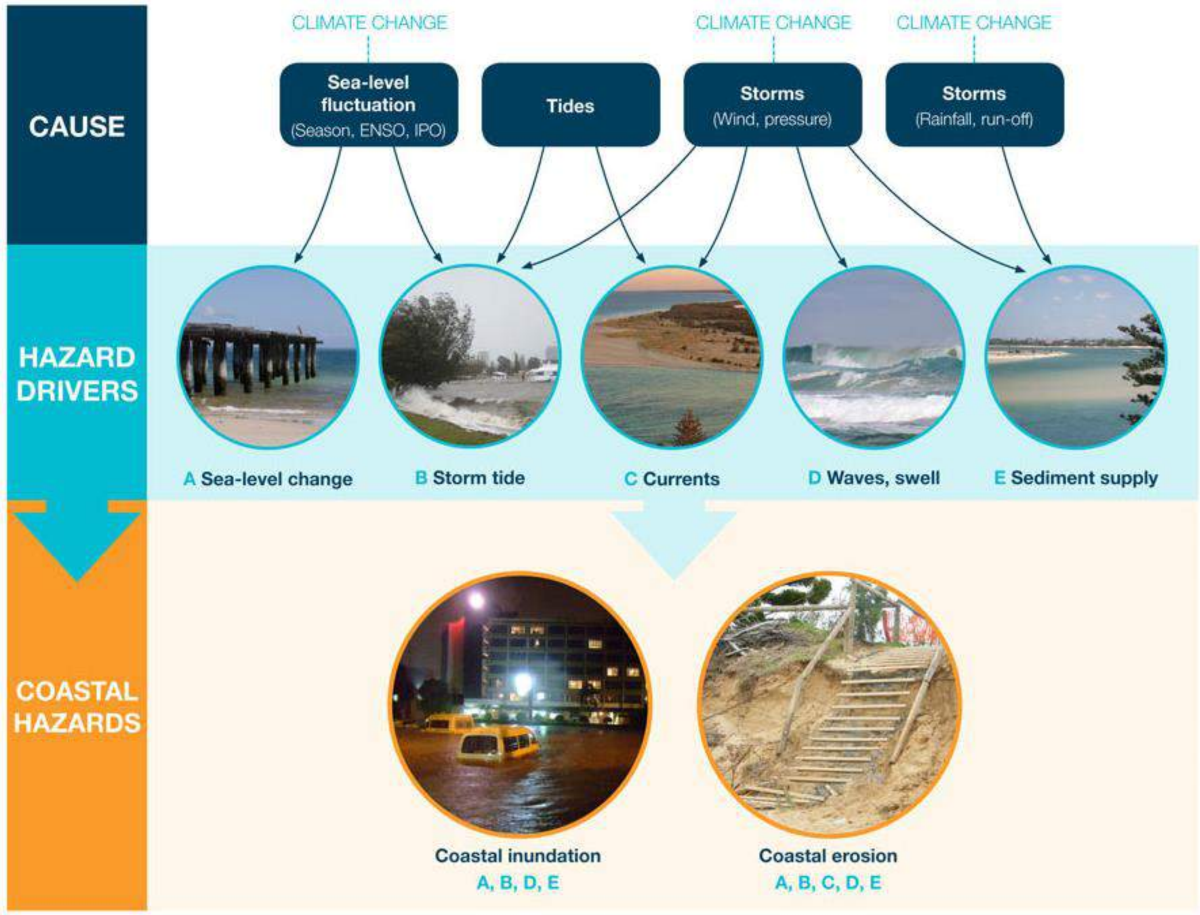

Figure 1. Diagrammatic view of exposures (causes) and hazard drivers and their relation to key hazards to coastal assets.

Source: CoastAdapt (2017)

Additional notes on anticipated climate futures, global climate change models and emissions scenarios, are provided in Appendix 3

3.3 Coastal Line

The Coastline to be used in this study was the Victorian version of coast prepared in the 2012 Spatially Enabling Coastal Assets Project (SECAP). This dataset is referenced as **SmartLine_Victoria_2008**.

This depiction was selected on the basis it provided:

- a significantly more accurate version of the coast than the VicMap framework dataset
- better representation of the inter-relationship between the coast and other coastal assets
- supported the generation of more accurate contextual attributes relating to the coast; and
- was significantly more consistent with datasets depicting anticipated increases in sea levels, and storm surge events resulting from climate change.

The version of the coastline used in this study included key attributes from the SmartLine dataset that were transferred to this more accurate depiction of the coastline using an automated spatial attribute transfer approach. Some attribute discrepancies or errors were observed to have arisen in this process. A brief description of the SmartLine_Victoria_2008 dataset is provided in Appendix 2.

3.4 Study Area

The Study Area selected for this project was defined as:

- Intertidal or sea side – the sea area to the 10m bathymetric depth contour, or 500m from the coast, whichever was greater
- Land side – land area 500m inland of the 10m height contour, or 500m from the coast, whichever was greater

A coastal study area extent was used for the purposes of confirming and quantifying the coastal assets that were to be reviewed as part of this study. Hence, assets that fell within this boundary were considered in this study and available for analysis of likely climate change impacts.

The study area boundary on the land side was required to incorporate all areas anticipated to be subject to sea level rise change and storm surge events by 2100. Given the 10m contour study area criteria, all potential inundation impacts were viewed to be accounted for within the defined study boundary.

A map view of this study area is provided in the following two Figures. Figure 2a shows the entire study area along the Victorian coastline with Figure 2b, Figure 2c and Figure 2d providing close up views of the west, central and east regions, respectively. Figure 3 shows a detailed view of the study area in relation to the Bellarine Peninsula and how this relates to projected and modelled sea level rises and storm surges.

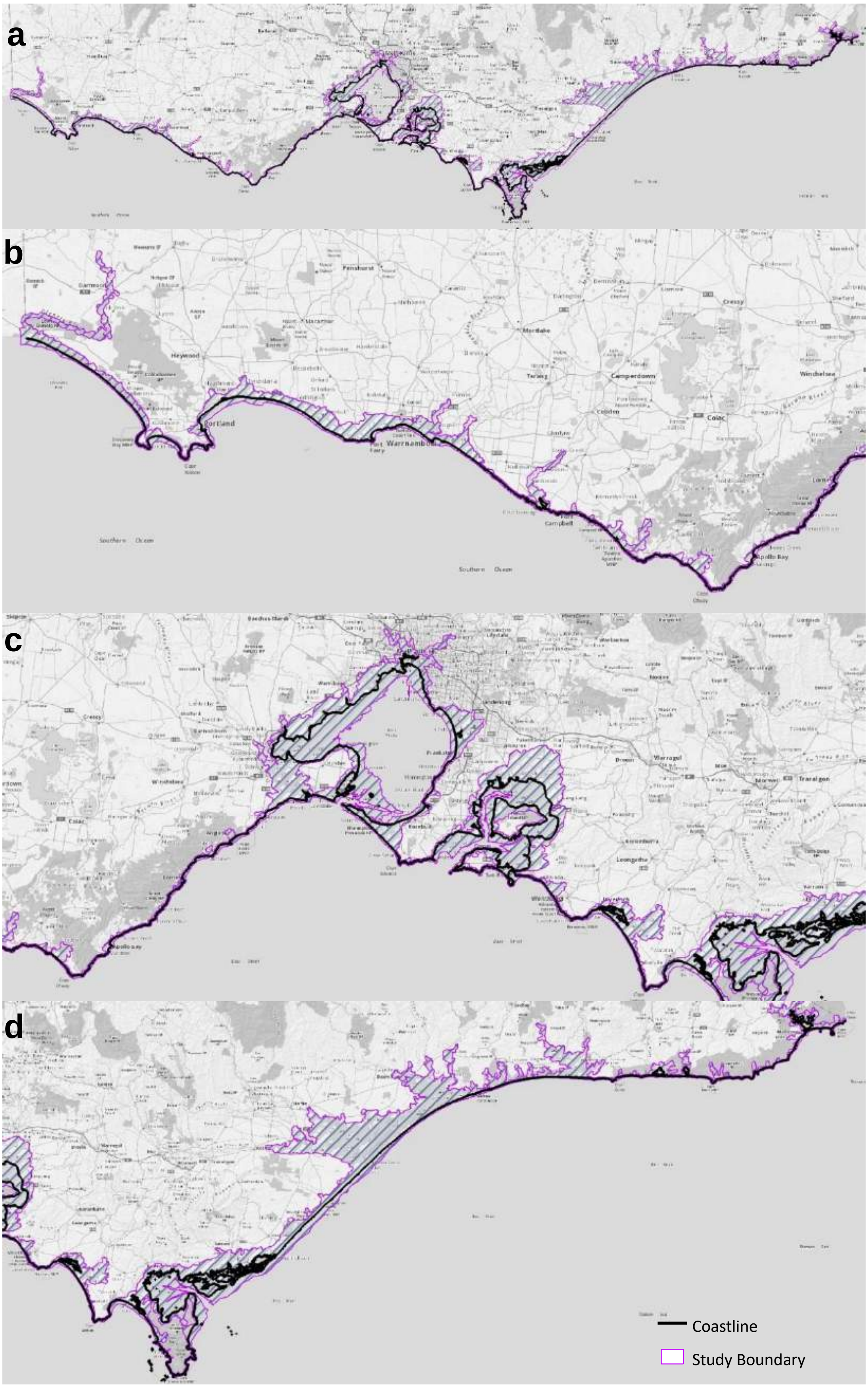

Figure 2. (a) Map view of the entire study area. (b) Map view of the western region. (c) Map view of the central region. (d) Map view of the eastern region.

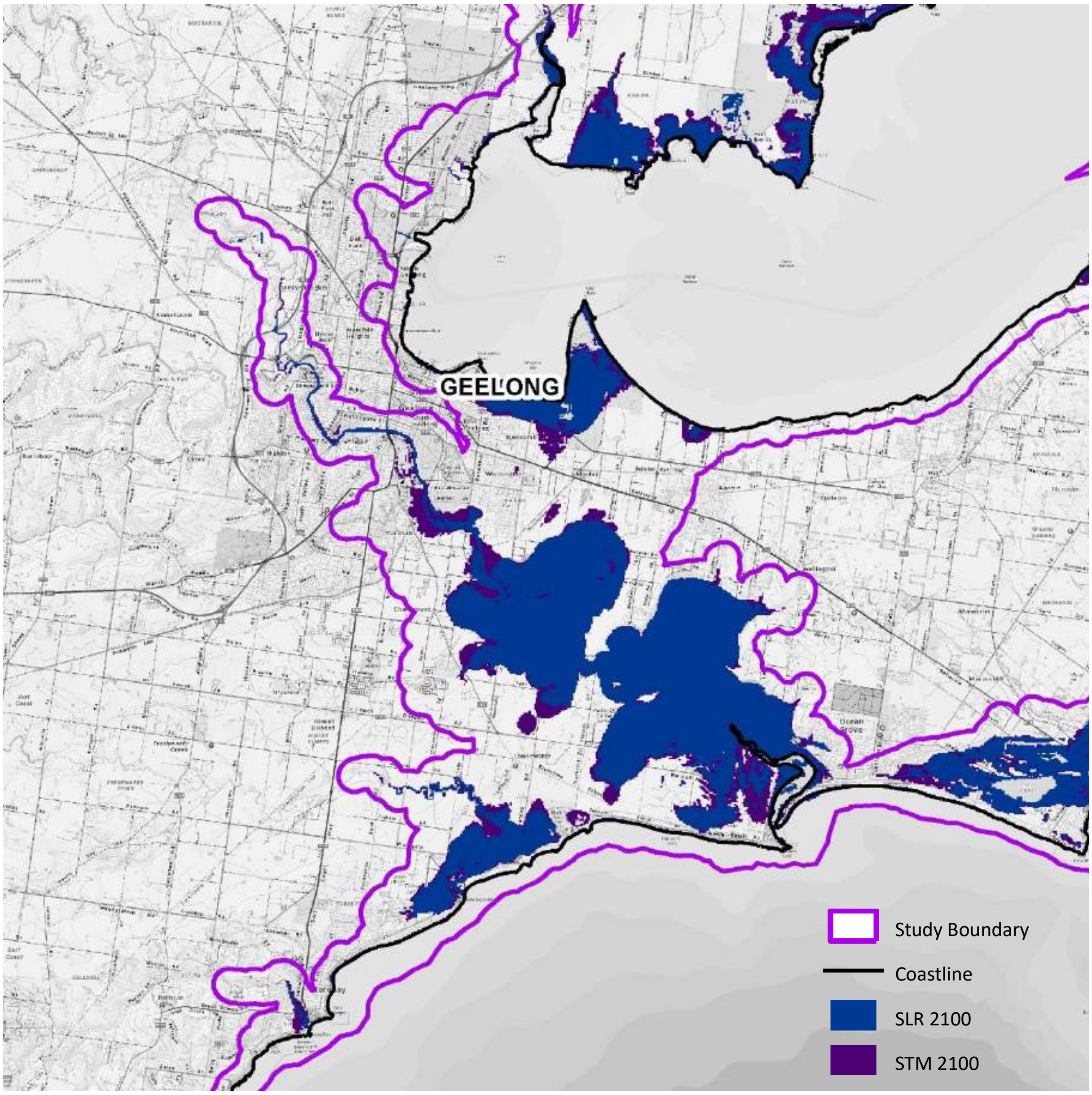

Figure 3. Detailed map view of study area boundary near Geelong and Bellarine Peninsula showing the coastline and study area boundary in black line. Area anticipated to be subject to Sea Level Rise to 87cm and Storm Surge in 2100 is shown. Figure shows how adopted study area accommodates these areas.

3.5 Use of Sediment Compartments

The coastal study area extent was divided up on the basis of published coastal secondary level sediment compartments and findings in relation to the coastline and coastal assets were presented using these compartments.

A coastal compartment, as defined on the CoastAdapt web-site, is 'an area in which coastal processes, and their effects on the geology of the coast, are broadly homogeneous. This site notes that the compartment boundary is usually a feature such as a headland or river mouth which effectively divides the compartment and its processes from its neighbour'.

'The coastal compartment approach provides a useful framework for coastal management and regional planning, since the compartments are derived from an assessment of linked coastal processes and landforms. The compartment boundaries act as natural barriers to sediment transport, enabling the area between boundaries to be treated as a semi-closed system with quantifiable sediment sources and sinks. The approach however, is applicable to the open coast and does not include detailed sedimentary processes in estuaries and coastal lakes.'

'The coastal compartments approach is being used in the United States, the United Kingdom and some parts of Europe, as it provides an effective framework to address issues such as sediment movement between rivers and the shoreline that can cross administrative boundaries.'

'Given the spatial and temporal variability in coastal sediment transport, a nested hierarchy of coastal compartments has been defined for Australia. Large primary compartments can define the external conditions for smaller secondary and tertiary compartment analysis. Primary compartments can be important in understanding local historic trends, contemporary processes and risks of broader erosion and accretion.'

Figure 4 shows how small tertiary compartments (bounded by red lines) fit within secondary compartments (shown in blue lines) and larger primary compartments (in yellow), and that each of these scales is suitable for different types of decision-making

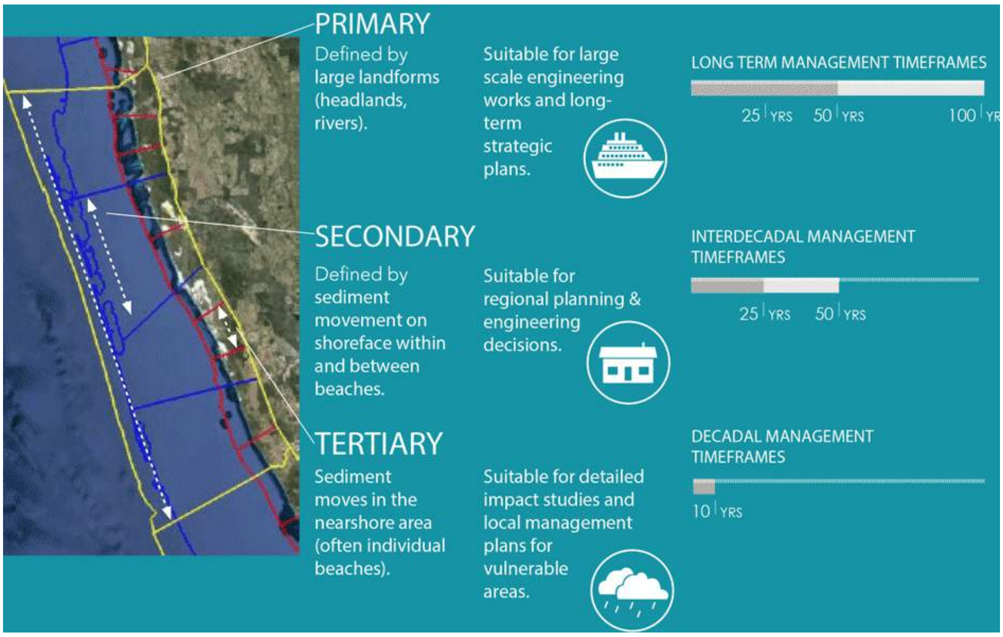

Figure 4. Coastal Compartment scales, use and timeframes.

Source: Thorn 2015.

CoastAdapt includes maps of primary and secondary coastal compartments and their attributes, together with further information on their use.

An important development in CoastAdapt is the assignment of a susceptibility ranking to each secondary compartment. This ranking is effectively a sensitivity ranking in relation to sediment movement. The rank is numbered from 1 to 5 as follows, and indicates the likelihood and nature of coastal change in each secondary compartment:

1. Accreting at present, and likely to continue in future
2. Stable and likely to start accreting in the future
3. Stable and likely to stay stable
4. Stable but likely to start eroding in future
5. Receding and likely to continue eroding in future.

This study has applied a refined version of this sediment sensitivity ranking to sections of the coast on the basis of the more detailed descriptions prepared for individual secondary compartments available on the CoastAdapt web-site.

PART 2 – OVERVIEW OF APPROACH

4. Impact Assessment Framework Background

4.1 Assessment Framework

As previously noted, this study drew in part on the approach adopted in the State-wide assessment of the likely impact of anticipated climate change on natural assets project (undertaken in 2014). In relation to coastal erosion this project applied an overall vulnerability assessment method, that was outlined and adopted in the: *Guidelines For Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012; Local Government Association of South Australia*. This method describes how likely exposure to climate scenarios, and sensitivity and adaptive capacity of assets to these climate changes, are used to assess the likely impact and vulnerability of assets to these changes. This process was developed by the Allen Consulting Group, 2005, and was based on that developed by the IPCC, 2007.

The conceptual framework on which this coastal erosion impact assessment process was based is presented below in Figure 5.

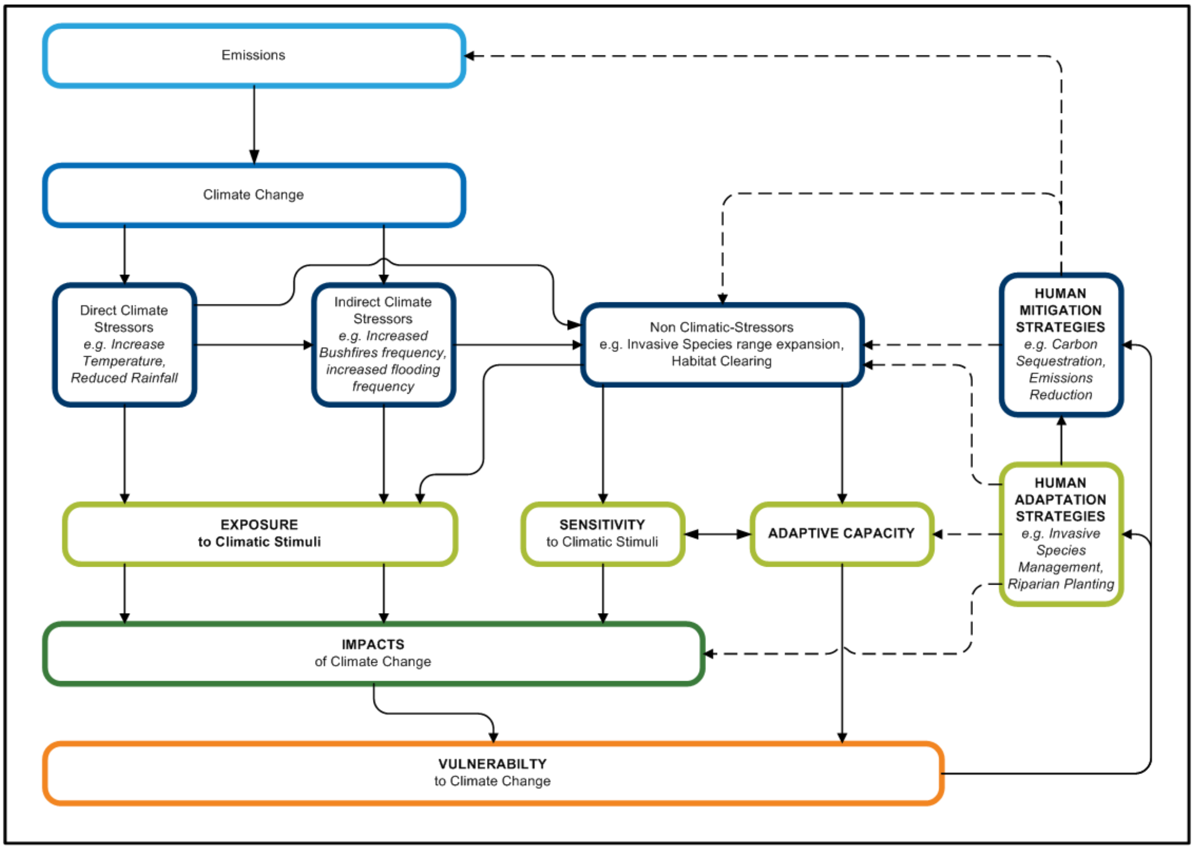

Figure 5. Conceptual framework for assessing vulnerability to climate change, showing relationships between exposure, sensitivity, impacts, adaptive capacity and vulnerability.

Solid lines indicate direct affective relationships between biophysical parameters (such as the impact of climate change on direct climate stressors, or of non-climate stressors on exposure to climatic stimuli). Dashed lines indicate the effects of human activity, including the impacts of climate change and adaptation and mitigation activities. (Adapted from: Riparian Ecosystems in the 21st Century: Hotspots for Climate Change Adaptation; Samantha J. Capon et al; Ecosystems (2013) 16: 359–381)

This process identifies asset types, their sensitivity to different climate exposure surfaces (climate scenarios), adaptive capacity, impact, and assessed vulnerability rating. This approach generates an impact rating on the basis of assessed asset sensitivity to different climate change exposure scenarios. The adaptive capacity of assets in relation to impacts is also assessed and used to assign asset vulnerability, where adaptive capacity relates to asset condition and context, or mitigating factors.

This coastal climate change impact assessment project involved application of the above process utilising spatial datasets available from DELWP and other stakeholders.

The key outputs of this process were intermediate and final spatial datasets that depict the assessed level of impact and vulnerability for sections of the coast for agreed climate change scenarios, and the assessed implications for associated coastal assets. Outputs of this project also included documentation (including processing steps, definitions, and assumptions, to support future application of the process developed.

Key definitions relating to this framework are presented in the following section.

4.2 Definition of Key Framework Terms

Vulnerability

The term ‘vulnerability’ is used in many different ways by various research communities, such as those concerned with secure livelihoods, food security, natural hazards, disaster risk management, public health, global environmental change, and climate change (Fussel and Klein, 2006). The glossary of the 2001 IPCC Assessment Report (Houghton et al., 2001; McCarthy et al., 2001) defines vulnerability (to climate change) as follows:

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

The IPCC describes vulnerability as a function of impact and adaptive capacity and “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity” (IPCC 2007). The components of exposure, sensitivity and adaptive capacity and their relationship to vulnerability are illustrated in Figure 5.

Again, in the context of this project, vulnerability (and hence the scope of the assessment) is defined as a “measure of possible harm” (Hinkel 2011). Harm to the coastal environment includes such things as a loss of habitat or species diversity, disruption to food webs, reduction in ecosystem services or loss of ecosystem resilience and the capacity to bounce back from stresses, reduced water quantity or quality or an increase in habitat fragmentation.

Other Key Definitions

The project adopted the following definitions of exposure, sensitivity and adaptive capacity in an effort to achieve a consistent understanding and interpretation of the proposed framework for this project. These definitions are based on those provided in “Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment; November 2012; Local Government Association of South Australia.”

Exposure: relates to the influences or stimuli that impact on a system. Exposure is a measure of the predicted changes in the climate for the future scenario assessed. It includes both direct stressors (such as increased temperature), and indirect stressors or related events.

In relation to the coast, exposure includes factors such as orientation, anticipated wave heights and energy, and the bathymetric profile, that amongst other factors influence the overall level of exposure for a given coastal segment.

Sensitivity: reflects the responsiveness of a system to climatic stressors or influences, and the degree to which changes in climate might affect that system in its current form. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes. This term is often used interchangeably with the term susceptibility. In this interpretation to coastal areas, sensitivity both relates to sensitivity to factors such as erosion.

Adaptive Capacity: is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The adaptive capacity of a system or society describes its ability to modify its characteristics or behaviour so as to cope better with changes in external conditions. The more adaptive a system, the less vulnerable it is. It is also defined as the property of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climate conditions. For the purposes of this project, adaptive capacity has been assigned in terms of the ability of the coast to adjust to climate stressors based on its current state. This includes coastal vegetation and man-made structures that protect the coast.

Other Key Coastal Climate Impact Assessment Terms

Other key terms used in this study and report, or that were related to some of the key concepts are briefly described below. Further terms and definitions can be provided in **Appendix 1**

Hazard: refers to the potential of a process, natural or otherwise, that has the potential to impact on a given unit area to a degree that may place that area at risk. In context of coastal areas, these hazards are primarily naturally driven and can include processes such as storms and sea level rise. However, anthropogenic influences on these processes are indirectly increasing the impact of the hazards upon the coastal fringes.

Impact: refers to the effect on the natural or built environment to particular hazards, including extreme events such as storms and other climate events. It relates to the exposure of an asset to a particular hazard and the sensitivity of that asset to that exposure.

Risk: is the potential of losing or gaining something of value based on particular actions or inactions. A risk assessment, or analysis, is the process in which these potential risks are evaluated and the projected consequences are defined based on this action or inaction. In relation to the coastal areas of Victoria risk analysis has helped define the projected outcomes to particular assets based on hazard, impact and sensitivity to coastal erosion and inundation.

4.3 Application of Impact Assessment Method

The approach applied in this coastal climate change impact assessment project to assess potential impacts and vulnerability of the coast and coastal assets to climate change adopted a simplified version of the above framework. This simplified framework is described in the following section.

This climate change impact assessment framework was only applied in relation to coastal erosion impacts and vulnerability. Inundation impacts were assessed using an independent but related process.

This process is described in detail in the following sections.

5. Overview of Impact Assessment Approach

5.1 Introduction

The coastal climate change impact assessment approach comprised the following three major stages:

1. Coastal Erosion Vulnerability Rating
2. Coastal Inundation Impact Rating
3. Application of Ratings to Coastal Assets

The first stage involved assessing the coastal strip in relation to coastal exposures relevant to coastal erosion, sensitivity of the coast to these exposures and adaptive capacity of the coast based on man-made and natural features that were believed to influence the impact of these exposures and sensitivities. This stage also involved considering the surrounding landscape associated with the coast and assigning a coastal erosion vulnerability rating to this surrounding area based on elevation, distance and land cover.

Stage two involved the application of modelling data in relation to anticipated coastal Sea Level Rise (SLR) and Storm Surge (STM) based on different timeframes, 1 in 100 year flood event scenarios, and the known distribution of Coastal Acid Sulphate Soils (CASS), to the study area.

The final stage used the outputs of the first two stages relating to erosion and inundation, and applied these findings to individual coastal assets. This process focussed on significant assets previously identified by DELWP in its 2015 risk assessment studies, and generated findings on the basis of secondary level coastal sediment compartments.

5.2 Study Area Assignment and Analysis

Coastline

This study used the SmartLine Victoria dataset with a nominal date of 2008 to define the Victorian coastline or coastal strip. All study findings are therefore referenced to this version of the Victorian coastline.

This SmartLine dataset was presented as a line feature, with a continuous unbroken line for the Victorian mainland coastal strip and a series of separate lines to represent islands. This version of the coastline excludes the Gippsland Lakes network, with the coastline crossing the Lakes Entrance opening, and extends in general to the commencement of brackish waters up major rivers such as the Glenelg River.

This coastline feature was divided into individual 50m segments for the analysis processes used in relation to coastal erosion. For each of these 50m segments, the bearing of the line represented in numerical degrees and the line centroid were identified and retained for use in the coastal erosion analysis process.

Study Area

The study area, as defined earlier in this report, was initially prepared as a single polygon feature. However, to support the analysis process there was a requirement to divide this area into smaller sub-units.

To assist processing and analysis the 23 secondary level coastal sediment compartments along the Victorian coastline were adopted as a suitable analysis processing unit. Hence, to process the entire study area into a fishnet grid for analysis purposes, where each individual grid cell was 50x50 metres in size, or 2500m^2 in area, separate fishnets were initially generated for each respective sediment compartment. This first step in the analysis process also involved classifying each grid cell in the study area as either: coast, land, or water.

5.3 Assignment of Erosion Vulnerability Rating

Conceptual Framework

A key element of the approach adopted to assess the likely impact of anticipated climate change on coastal assets was to consider the proximity of coastal assets to the coastline itself.

Hence, the overall approach involved assigning a coastal erosion impact and vulnerability rating to each 50m section of the coast, and then using the 50m grid cells to assign a coastal erosion rating to areas adjacent to the coast. These attributes were then assigned in the form of an impact assessment profile to individual coastal assets.

The conceptual framework used to assign a coastal erosion impact and vulnerability rating to each 50m section of the coast consisted of a simplified version of the framework presented in the previous section of the report.

Figure 6 provides a view of the simplified assessment framework applied in relation to coastal erosion impacts and vulnerability.

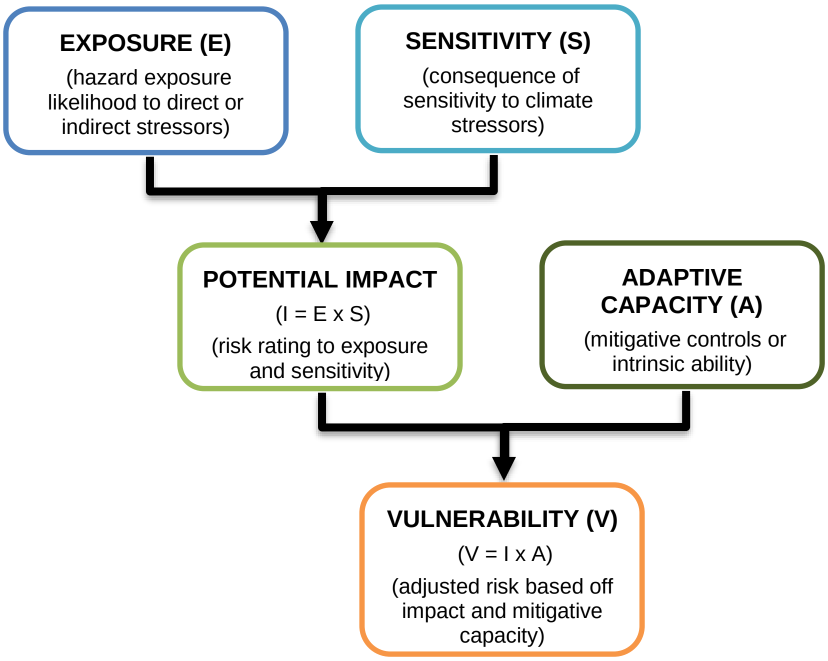

Figure 6. Climate change impact and vulnerability assessment framework as applied state-wide for coastal erosion.

A detailed explanation of the factors applied using this framework is provided in Section 6.

An explanation of the high level conceptual components of the framework within which these factors were applied, and how they were combined is provided in this section. These components include Exposure, Sensitivity and Adaptive Capacity which were combined to generate a Coastal Erosion Vulnerability rating.

Each coastal vulnerability factor incorporated into the framework was assigned a value from 1 to 5, relating to an assessed ratings of very low to very high.

- 1 – Very Low
- 2 – Low
- 3 – Moderate
- 4 – High
- 5 – Very High

Exposure (E)

Exposure was assessed on the basis of particular attributes of the coast that were viewed to directly, or indirectly, influence the level to which a section of coast will be exposed to anticipated climate change, particularly increases in severe storm events. The six attributes on which the exposure rating was based comprised:

- Coastal Type – Open Coast or Re-Entrant
- Orientation – Dominant direction a coastal segment faces
- Wave height
- Wave energy
- Fetch – The distance to open water, perpendicular from a coastal segment
- Bathymetric profile – Distance from the coast to a depth of 20m

Sensitivity (S)

Sensitivity of the coast to anticipated climate change stressors, particularly increases in severe storm events, was assigned on the basis of the following two attributes:

- Erodibility of the coast based on its geomorphology
- Sediment compartment sensitivity rating – that refers to the likely level of sediment movement in relation to SLR and STM

Erosion Impact (I)

Impact was determined through combining sensitivity and exposure, where areas assessed to be most likely impacted were those with a high level of likely exposure and high level of sensitivity.

For each of the two factors, Exposure and Sensitivity, the contributing attributes were combined with equal weighting. These two factors are therefore multiplied together to determine the Impact rating for a coastal segment.

Adaptive Capacity (A)

Adaptive Capacity was a measure of the resilience of the coastal strip to given impacts. This capacity could either come in the form of man-made structures, natural structures or natural vegetative cover. The attributes used to assign a likely Adaptive Capacity rating to a section of coast were:

- Reefs – Proximity to reef strata based on the presence or absence of reefs on a perpendicular transect from the coast for an agreed distance.
- Intertidal vegetation – Percentage cover of intertidal vegetation within one kilometre of a given coastal segment
- Coastal Vegetation – Percentage cover of land-based vegetation within 50m of the coast
- Engineered Structures – Presence and type of structure

Coastal Erosion Vulnerability Rating (V)

Vulnerability was determined through combining Impact and Adaptive Capacity, where areas assessed to be most highly impacted may be less vulnerable where adaptive capacity elements were present to lessen the likely impact when compared with areas with the same assessed level of likely impact, but without the same adaptive capacity elements.

An adaptive capacity rating was assigned to a section of coast by assigning the highest value for any of the attributes contributing to adaptive capacity.

The resultant adaptive capacity rating was then multiplied with the Impact rating to produce the final Coastal Erosion Vulnerability Rating.

Assignment of Erosion Ratings to the Coast Line

Each of the aforementioned attributes and ratings were assigned to the unique 50m segments of the SmartLine dataset derived coastline.

Assignment of Coastal Erosion Vulnerability Rating to Study area

To assign a coastal erosion rating across the study area, the Victorian coastline dataset comprising 50m segments of the coast with their uniquely assigned attributes, including coastal erosion vulnerability and impact ratings, was then used to assign an erosion rating to 50m by 50m grid cells that correspond with or comprise the coast.

This erosion rating was then assigned across the full study area using a near analysis function which considers distance, elevation and land use and cover in the assignment process. Hence, a decay factor was applied in the erosion rating assignment process coast based on:

- Distance from the coastline
- Height above the coastline
- Land use and land cover

For elevation and distance, an inverse exponential relationship was applied to determine decay from the coast. Hence, the decay for elevation increments closest to sea level was greatest with this declining at higher elevations to a limit of 20m in elevation above sea level where the decay score was zero.

Differing land uses were also anticipated to influence the manner in which coastal erosion ratings assigned to the coastline were transferred across the study area. The decay factors applied based on this relationship were:

- Native vegetation – 30% decay
- Non-Native woody vegetation – 20% decay
- Disturbed, Bare Ground or Farm-Land – 10% decay
- Built-up environment, Urban – 0% decay

5.4 Assignment of Inundation Impacts

Coastal Inundation Impacts were assessed on the basis of:

- Anticipated Sea Level Rise (SLR) and Storm Surge (STM) for 2040, 2070 and 2100.
- Extent of 1:100 year flood events
- Presence of Coastal Acid Sulphate Soils (CASS)

This processed involved assigning the presence or absence of SLR and STM for each or the selected periods, 1:100 year flood event, and CASS rating, to each 50m by 50m grid cell in the study area.

With SLR and STM, this involved a simple attribution of presence or absence of either SLR or STM to a given grid cell.

Flooding on the coast may also result from significant inland rain events. The process of assigning the flood event attribute to a given grid cell within the study involved initially assigning a rating based on the 1:100 year flood event data. However, with the advent of SLR encroaching on the coastal land area, it was recognised that these flood events will potentially cover less land area over time. Therefore, the area of land impacted by flood was reduced for each of the timeframes due to increases in SLR and STM.

The assignment of a CASS rating involved initially identifying all areas modelled or assessed to have potential CASS and assigned each grid cell on this basis. However, given CASSs are activated to produce sulphuric acid during wetting and drying events, it was important that the process applied identified where these soils occurred in combination to areas subject to likely flood or STM events.

5.5 Assignment of coastal climate change Impact rating to assets

Coastal assets within the study area were initially categorised into four broad groups:

- Coast
- Economic
- Social
- Environmental

After compiling a spatial representation of a large number of assets in each of these categories, a focus was placed on the significant assets previously identified by DELWP in its 2015 risk assessment studies.

These assets were represented spatially as either point, line or polygon features. In order to collate the coastal erosion and inundation ratings for each asset, different approaches were applied to determine the relative scores assigned to an asset. Hence, the approach used comprised:

- Point - the scores for the cell that the point fell within as well as a selection of adjacent cells to a search radius of 25m was used.
- Line - the scores of the cells that the line fell in was used. The length of the asset, in kilometres (km) was also recorded.
- Polygon - the scores of the cells that the polygon footprint fell in was used. The area of the asset, in hectares (ha), was also recorded.

Parameters and scores assigned to individual assets in the form of an asset profile comprised:

for Coastal Erosion

- Quantity and percentage of asset impacted by High and Very High Coastal Erosion Vulnerability Rating.

for Inundation

- Quantity and percentage of asset impacted by SLR, STM, 1 in 100 year flood events and activated CASS.
- Two timeframes for SLR and STM relating to anticipated change by 2040 and 2100.

6. Coastal Erosion Rating - Method

6.1 Data Inputs

Coastal SmartLine Inputs

SmartLine was used as a key starting point to assess coastal vulnerability. This dataset defines the coastline and was presented as a single polyline feature that contains a multitude of attributes, such as backshore, subtidal or intertidal information, landform and geology or geomorphology. Each section describes a unique segment of the coast and demonstrates significant changes in the characteristics of the coastal strip.

SmartLine data and extended attributes, such as erodibility and instability, was created by Geoscience Australia and provided through NCCARF and the CoastAdapt program as well as the OzCoast platform.

For assessment purposes, SmartLine was divided into fifty metre segments, and attributed further with derived variables.

The geometry of the SmartLine spatial dataset, together with its attributes, provided direct input for the assignment of:

- Orientation
- Fetch – Distance to open water
- Coastal Type
- Erodibility

Wave Model Inputs

Wave climate data inputs for wave height and wave energy were derived from the CAWCR Wave Hindcast dataset. This dataset used the WaveWatch III v4.08 wave model, as developed by the National Oceanic and Atmospheric Administration (NOAA) and the National Centre for Environmental Prediction (NCEP). The Wave Hindcast dataset also makes use of the NCEP Climate Forecast System Reanalysis (CFSR) to force the WaveWatch III model to generate three hourly, monthly and yearly gridded data between the years of 1979 to 2010. The model was run on a global grid with a resolution down to 4 arcminutes, approximately 7km^2, in the Australian region. Data was sourced from the Australian Wave Energy Atlas. The links provided through this service were averaged surfaces between the years of 1980 to 2010, rather than individual years.

This dataset was used for several variable inputs including:

- Wave Energy
- Wave Height
- Wave Direction

For wave energy and wave height, the outputs from the Australian Wave Energy Atlas grid were directly used. Wave direction was used as a guide to assign a rating to different orientation of the coast based on the coastal zone or section (where four zones were identified, east, central, west and re-entrant).

Bathymetric Data Inputs

The bathymetric profile of the intertidal zone was determined primarily using the Victorian Coastal Nearshore Bathymetric Elevation dataset. This provides 5m contour intervals derived from LiDAR derived bathymetry, generally extending out to the 20m contour interval mark.

Other data inputs included bathymetric contour arcs within each of the major embayment's and across Bass Strait, comprising:

- Bass Strait
- Port Phillip Bay
- Westernport Bay
- Corner Inlet
- Mallacoota Inlet

Sedimentary Compartments

Secondary level coastal sedimentary compartments were sourced from the Australian Coastal Sediment Compartment data package. Secondary inputs for compartment sediment sensitivity were sourced from National Climate Change Adaptation Research Facility (NCCARF) and their CoastAdapt project.

Other Layers

Reef strata datasets were sourced and supplied through the Marine Biodiversity and Policy Division of DELWP through the SUBSTRATA100 layer.

Coastal Mangrove and Saltmarsh spatial datasets were sourced and supplied through the Marine Biodiversity and Policy Division of DELWP through the Intertidal_EVC layer and the Boon 2011 Mangroves and Costal Saltmarshes of Victoria study (Boon et. al., 2011)

Seagrass Mapping was sourced and supplied through the Marine Biodiversity and Policy Division of DELWP through multiple collated datasets, including:

- Port Phillip Bay Intertidal Marine Vegetation
- Western Port Intertidal Marine Vegetation
- Corner Inlet Seagrass and Intertidal Marine Vegetation
- Mallacoota Inlet Seagrass and Intertidal Marine Vegetation
- Anderson Inlet Seagrass and Intertidal Marine Vegetation
- Shallow Inlet Seagrass and Intertidal Marine Vegetation
- Wingan Inlet Seagrass and Intertidal Marine Vegetation
- Tamboon Inlet Seagrass and Intertidal Marine Vegetation
- Sydenham Inlet Seagrass and Intertidal Marine Vegetation

Full dataset listings can be located in **Appendix 5**: Data Sources and **Appendix 6**: Reference Documents.

6.2 Exposure

Attributes of the coastline viewed to influence the likely exposure of the coast to climate related change factors, and for which state-wide spatial datasets could be sourced and provided at a suitable resolution and differentiation, were:

- Coastal Type – Open Coast or Re-Entrant
- Orientation – Dominant direction a coastal segment faces
- Wave height
- Wave energy
- Fetch – The distance to open water, perpendicular from a coastal segment
- Bathymetric profile – Distance from the coast to a depth of 20m

These attributes were assigned to 50m sections of the coast.

Coastal Type

A coastal type attribute was used to differentiate between open coastal systems and re-entrant shorelines.

Open coast includes open exposed shorelines that receive direct or refracted ocean waves. These could also include locally formed wind-generated waves. Re-entrant sections of coast includes waterways or estuarine systems that are permanently or intermittently connected to the ocean. These systems are influenced by tidal variations and other sea-level changes, but are wholly or partially sheltered from ocean waves. This term was also used to describe embayment areas along the coastline. Since some embayment areas, including Port Phillip Bay and Western Port, are geographically large, coastal attributes such as bathymetric profile, fetch and orientation have an effect on the wave climate and exposure of the coast for these areas. However, it was noted that this was viewed not have as a great an impact as was expected along the open coast.

The coastal type was derived from the SmartLine coastal strip dataset. The ratings assigned to the coast are outlined in Table 3, with Figure 7 presenting a map representation of this attribute as applied to the coastline dataset.

Table 3. Coastal Type Scoring

Coastal Type	Score	Category
Open Coast	3	Moderate
Re-Entrant	5	Very High

Figure 7. Map view showing initial assignment of open verses re-entrant.

Orientation

Orientation refers to the direction of the coast perpendicular to the water, or rather the direction a particular section of coast faces. This was used to define the exposed face of the coastline and the prevailing direction of waves, wind and other factors to a section of coast.

For each 50m segment of the coastline, the dominant cardinal direction of the coast was expressed numerically. Using this value the perpendicular direction was defined and used to identify the orientation of the coast (or rather the direction it faces).

In assigning this attribute, it was noted that it was of value to also classify the Victorian coastline into four distinct zones;

- Western – from the SA border at Discovery Bay to Cape Otway
- Central – from Cape Otway to the point of Wilsons Promontory
- Eastern – from the point of Wilsons Promontory to the NSW border east of Mallacoota
- Embayments – all coastal embayment areas and re-entrants

Figure 8 presents the sections of the coast within each of the four major identified zones that comprise the Victorian coastline.

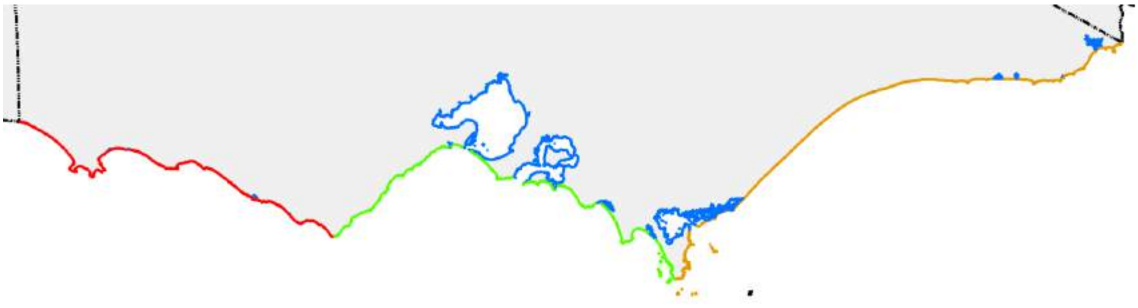

Figure 8. Boundary assignment of the four major identified coastal zones.

Each of these zones were expected to have different orientations that reflect greater and lesser levels of likely impact from wave action. For example, the western zone was more greatly impacted by SSW to SW wave directions. The importance of these directions for each zone was scored accordingly to their anticipated coastal impact. The predominant direction for each zone was determined using the direction variable in the Wave Hindcast dataset. The rating developed using the Wave Hindcast dataset and applied in this study is presented in Table 4.

Table 4. Orientation Scoring

Direction	Western	Central	Eastern	Embayment - Major				Embayment - Minor		
				PPB West	PPB East	Western Port	Corner Inlet	Western	Central	Eastern
N	1	1	1	1	1	2	2	1	1	1
NNE	1	1	1	1	1	1	3	1	1	1
NE	1	1	1	3	1	1	4	1	1	1
ENE	1	1	2	2	1	1	4	1	1	1
E	2	1	4	2	1	1	4	1	1	2
ESE	2	2	5	4	1	2	4	1	1	3
SE	3	3	5	5	2	3	3	2	2	3
SSE	3	4	5	5	3	3	2	2	2	3
S	4	4	5	5	4	3	1	2	2	3
SSW	5	5	4	4	5	5	1	3	3	2
SW	5	5	2	3	5	5	1	3	3	1
WSW	5	5	3	3	5	5	1	3	3	1
W	4	4	1	2	4	4	2	2	2	1
WNW	2	2	1	3	4	3	4	1	1	1
NW	1	1	1	2	3	3	4	1	1	1
NNW	1	1	1	1	2	3	3	1	1	1

Figure 9 presents the final orientation based rating assigned to each 50m section of the Victorian coast based on its coastal zone and orientation.

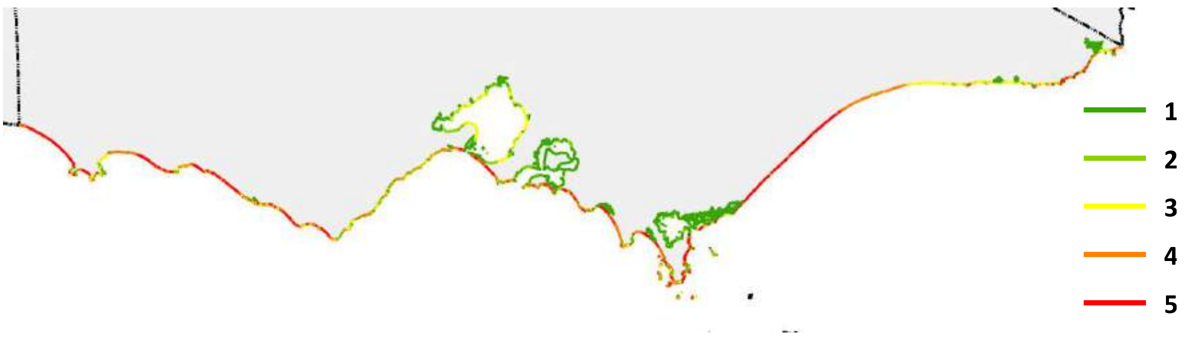

Figure 9. Map view showing initial assignment of dominant direction coastal sections face based on the Coastline 2008 dataset.

Fetch - Distance to Open Water

Fetch was defined as the amount or distance of open water perpendicular to the coast. In this study fetch was assessed in terms of classifying a section of coast on the basis of a series of open water distances intervals from the coast. Fetch of the coastline was important since it influences, for example, the impact winds of a particular direction may have on the coast through the generation of waves. The scoring system applied in this study is outlined in Table 5, with Figure 10 presenting a map view of the rating assigned to each 50m section of the Victorian coast.

Table 5. Distance to Open Water Scoring

Distance from Coastline	Score	Category
<= 1 km	1	Very Low
2 km	2	Low
3 km	3	Moderate
4 km	4	High
>= 5km	5	Very High

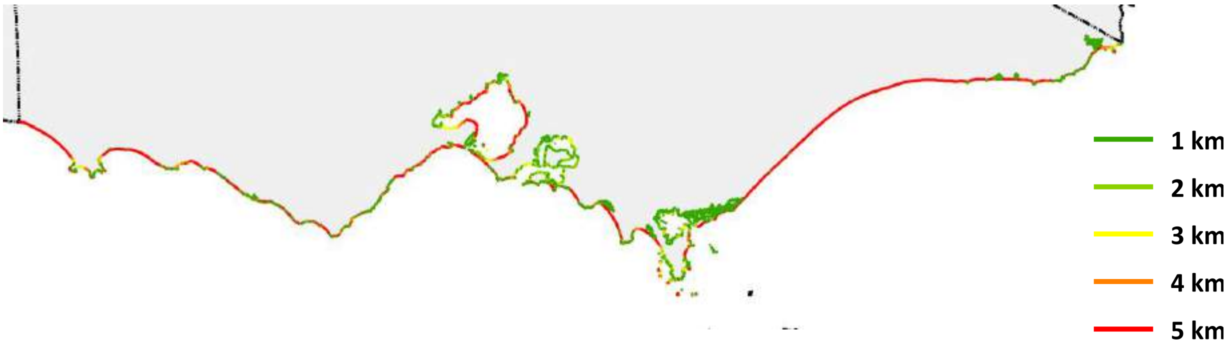

Figure 10. Map view showing initial assignment of fetch to coastal sections.

Wave Height

Wave height, or 'Significant Wave Height', was defined as the average height of the largest one third of a wave. This has been related back to the mean breaker wave height at the beach. The variable applied in this study was derived directly from the wave climate dataset provided as part of the CAWCR Wave Hindcast dataset. More specifically, the attribute applied in this study was the averaged wave height over the year, as supplied through the Australian Wave Energy Atlas which was the averaged wave height between the years 1980 to 2010.

It was noted that while the height of waves hitting a section of coastline varied between west, east and central zones along the coast, the relative pattern and scale was fairly consistent between individual months. Hence, the annual average wave height was determined to be suitable input for this variable. Table 6 presents the rating assigned and used in this study based on the average wave height values identified in the dataset.

Table 6. Wave Height Scoring

Wave Height (m)	Score	Category
< 0.4	1	Very Low
0.4 – 1	2	Low
1 – 1.5	3	Moderate
1.5 – 2.25	4	High
> **2.25**	5	Very High

Wave Energy

Wave Energy in this study refers to the Wave Energy Flux or Wave Power Density. It was a measure of the available power in the wave, calculated as the kilowatts per metre of wave crest width (kW/m).

The variable used in this study was derived directly from the wave climate dataset provided in the CAWCR Wave Hindcast dataset. This study assigned a wave energy rating based on the average wave energy flux values for the months of August and September. These two months were selected on the basis they presented on average the two highest values for the whole year. This was particularly noticeable along the western zone of the Victorian coast from Discovery Bay down to Cape Otway. The rest of the coast experiences a fairly consistent wave energy profile on a monthly basis when summed or averaged. Hence, the rationale behind using these two months was that they are the key months that identify a significantly greater relative impact from exposure to greater wave energy on the western coast than is typical in other months.

The values applied in this study using the average wave energy flux values for the months of August and September, and directly obtained from the Wave Hindcast dataset, are presented in Table 7.

Table 7. Wave Energy Scoring

Wave Energy (kW/m)	Score	Category
< 3	1	Very Low
3 – 8.5	2	Low
8.5 – 20	3	Moderate
20 – 45	4	High
> 45	5	Very High

Bathymetric Profile

The bathymetric profile in the study area was defined as the distance from the coastline out to the 20m bathymetric depth marker. This was used as a proxy for the coastal bathymetric slope profile and was viewed as an effective measure of the likely impact wave movement and volume of water has when it reaches the coast. The bathymetric slope can help determine the wave climate reaching the shore, in that wave energy, wave height and other factors can be redistributed due to wave refraction, shoaling and friction of the water along the sea bed. The bathymetric slope profile can therefore influence wave behaviour along the coast.

A greater slope value indicates a sharper drop into deeper water, and hence a shorter distance to the twenty metre depth marker. In this scenario the wave climate has remained largely unchanged and more energy and height has reached the coast. A shallower slope indicates a gradual change, such as experienced in intertidal mud flats or gentle inner bay beaches. These areas have a greater distance to the 20m depth marker resulting in areas close to shore experiencing a very different wave climate to than in the deeper water.

Table 8 provides the ratings assigned in this study to each 50m section of coast based on the distance to the 20m bathymetric contour in a perpendicular direction to the coast.

Table 8. Bathymetric Profile Scoring

Distance from Coastline (m)	Score	Category
> **2,000**	1	Very Low
1,000 – 2,000	2	Low
500 – 1,000	3	Moderate
150 – 500	4	High
< 150	5	Very High

Coastal Exposure – Overall Rating

An overall Coastal Exposure rating was derived by combining the scores assigned to each of the six contributing exposure related attributes identified earlier in this section. Each of the exposure attributes was assigned an equal weighting with the contributing attribute scores summed and then divided by 6 to provide a final rating from 1 to 5, with 1 designating a Very Low rating and 5 a Very High exposure rating.

Figure 11 presents a view of the overall Coastal Exposure rating generated for the full Victorian coastline. The open coastlines were noted to have higher exposure ratings due to how they score in relation to exposure attributes. The western coasts were identified to have higher ratings in general to those in the east.

Figure 11. Map view showing Coastal Exposure assignment Victorian coastline.

6.3 Sensitivity

Erodibility

The erodibility of a shoreline segment in this study was determined using the erodibility attribute contained in the SmartLine dataset. The basic definition of erodibility, as used within SmartLine, was the response of the coastal landform to coastal hazards and processes, such as sea level rise and inundation. This definition was primarily based on coastal geomorphology which results in a sandy beach, for example, as defined in SmartLine, to be assigned a higher erodibility rating than a hard rock coast.

The SmartLine erodibility attribute contains a rating from low to high which has been directly applied to assign an erodibility score for use in this study. This erodibility rating based on the SmartLine attribute is presented in Table 9. Figure 12 presents the erodibility ratings as applied to Victorian coastal segments and used in this study.

Table 9. Erodibility Profile Scoring

SmartLine Coastal Landform Erodibility Type	Score	Category
Dominantly artificial shores	1	Very Low
Dominantly hard rock shores	2	Low
Dominantly soft rock shores	3	Moderate
Dominantly undifferentiated soft sediment shores	4	High
Dominantly sandy shores	5	Very High

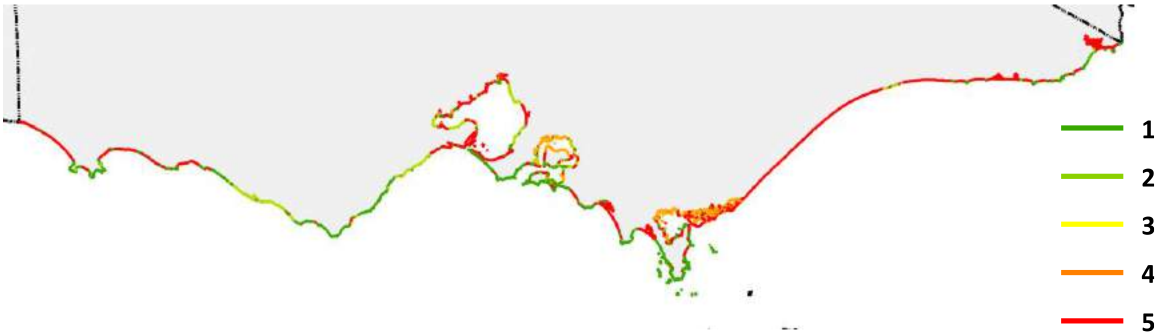

Figure 12. **Map view showing assignment of erodibility ratings based on the Coastline 2008 dataset.**

Compartment Sediment Sensitivity

The general dynamics and associated sediment budgets for the Australian coast have been broadly defined and were available on the OzCoast website. These coastal processes that influence sediment movement and coastal response, help define the sensitivity of the shoreline to recession or accretion in the face of coastal processes, including sea level rise and inundation.

For each of the 23 secondary level coastal compartments along the Victorian coast, the movement of sediment within these compartments has been described and the sensitivity of the coast to this movement, in the face of sea level rise, has been scored appropriately. A rating of 1 to 5, has been assigned to each secondary compartment, where 1 indicates a shoreline that was accreting sediment due to sea level changes, 3 indicates stable shorelines and 5 indicates shorelines that are receding quickly. Due to their size, secondary compartments could have multiple sensitivity ratings depending on the variability in coastal landforms and geomorphology.

The OzCoast website also contains a detailed description of sediment sensitivities and movements within each compartment that provides locational data and landform descriptions that help determine where to more accurately assign scores at a sub-compartment level. For this study a refined scoring of sediment compartment sensitivity was manually attributed to each coastal segment based on these more detailed descriptions.

Coastal Sensitivity – Overall Rating

An overall Coastal Sensitivity rating was derived by combining the scores assigned to each of the contributing sensitivity related attributes identified. Each of the sensitivity attributes was assigned an equal weighting with the contributing attribute scores summed and then divided by 2 to provide a final rating from 1 to 5, with 1 designating a Very Low rating and 5 a Very High sensitivity rating.

Figure 13 provides a view of the overall Coastal Sensitivity rating generated for the full Victorian coastline. Significant areas of the eastern coastline in Gippsland were noted to have higher sensitivity ratings than the western coastline due to the dominance of the sandy coast type.

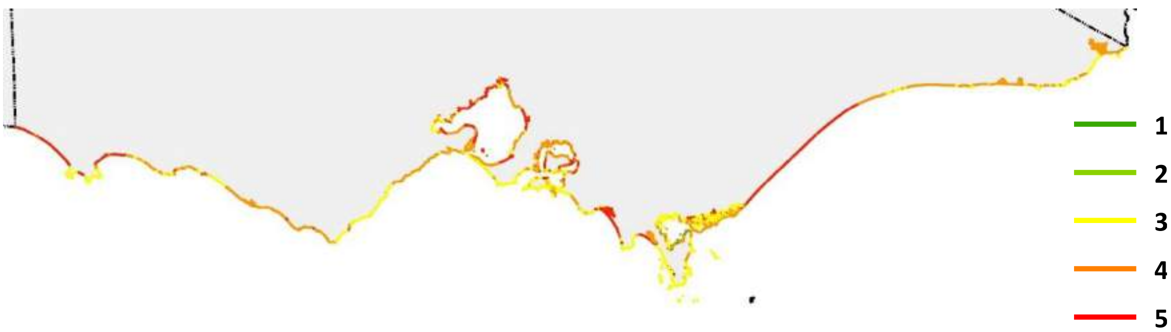

Figure 13. **Map view showing Coastal Sensitivity assignment Victorian coastline.**

6.4 Adaptive Capacity

Engineered Coastal Structures

Human intervention along the Victorian coast was viewed in this study to be one of the adaptive capacity attributes that influence the potential impact of coastal processes and hazards. Built structures, including breakwaters, seawalls, revetments and groynes, can fix the shoreline in place, stabilise the underlying strata and prevent coastal processes and exposures that may be viewed as detrimental to the coast. These structures can also alter the dynamics of coastal areas. Structures that sit out into the water can alter wave climate and sediment movement, and structures that sit on the shore can stop sediment naturally moving around along the coast.

Two coastal asset engineered structures data layers were sourced and used in this study. The principal layer was a protective structure condition analysis dataset prepared in 2013. This dataset provided attributes such as structure type and material, where protective structures included, seawalls, breakwaters and revetments, and for each structure a constructive material such as wood or rock was also identified. The VicMap Water Structures dataset was also utilised to provide additional structure type information not contained in the primary layer. For example, this second dataset contained information on causeways, launching and boat ramps as well as some additional wharves.

To assign an adaptive capacity rating to the coastal segment that contains these protective structures, a proximity analysis was undertaken. A proximity distance of 10m from the coast to the structure was applied. Using this criteria, the process only considered structures that occur on the coast or effectively adjoin it. Further to this, a visual check was undertaken in the areas where these structures were located to determine if the correct structure type was assigned. This was essential for areas that contained multiple assets, such as marinas where a wharf, breakwater and launching ramp occur in the same area, or in regions where groynes abut a seawall. In these scenarios the primary structure that dominated the area was chosen and the proximity analysis adjusted accordingly.

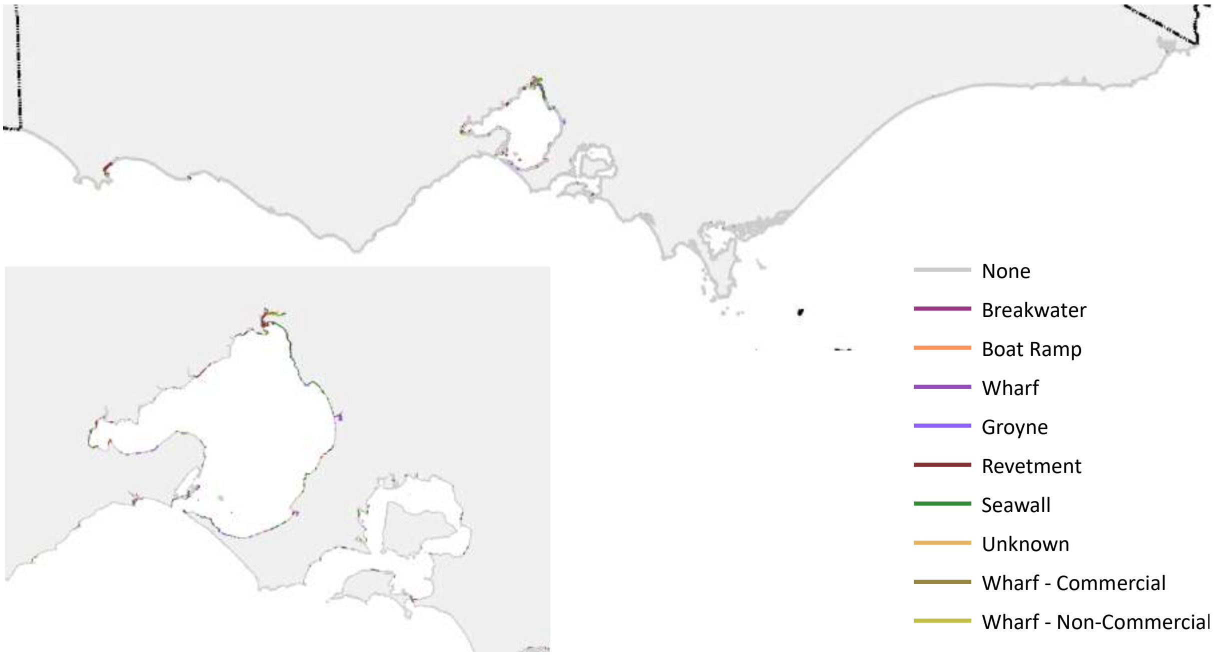

Figure 14. Map view showing the location of Engineered Coastal Protection structures along the Victorian coastline and within the Port Phillip Bay region.

Attributes from the primary and secondary coastal structures datasets were combined to identify five broad groupings and scored accordingly, as presented in Table 10. Figure 14 presents a view of the adaptive capacity dataset relating to coastal engineered structures along the Victorian coastline and within the Port Philip Bay Region.

Table 10. Engineered Coastal Structure (high level) Scoring

Coastal Protection Structure Type	Score	Category
Seawall, Breakwater – Masonry/Stone	1	Very Low
Seawall, Breakwater – Wooden. Revetment – Masonry/Stone	2	Low
Groyne – Any. Revetment – Wooden	3	Moderate
Launching Ramp	4	High
None	5	Very High

Reefs

Reef were viewed to have a mitigative impact on the wave climate which in turn could lessen the exposure of the coast to particular processes and reduce the sensitivity of the coastline to erosion and inundation. Reefs in the near-shore environment can perform as natural breakwaters or barriers to incoming waves and reduce wave energy and height. In this study reefs in the near-shore environment and their proximity to the coast were assessed. The source input used was a reef strata dataset that provided reef type and location. The dataset was used in combination with a bathymetry near-shore elevation model that was used to extract reefs that were within a 20m water depth. Using this subset of reefs, a proximity analysis was undertaken to identify 50m segments of the coast for which reefs were present within a distance of 500m. This process identified where a reef was present in the near-shore environment. A secondary (bearing analysis) process was also applied that involved using a line perpendicular to the coast to identify where a reef was present directly in front of a coastal segment to a distance of up to 1km. The proximity and bearing analysis were combined into one scoring system to identify where a reef was present. The result was scored using the ratings presented in Table 11.

Table 11. Reef Presence Scoring

Reef Presence Status Type	Score	Category
No Reef	1	Very Low
Reef Present	5	Very High

Intertidal Vegetation

Vegetation in the intertidal zone, such as seagrass, seaweed and mangroves, can act as an energy dampener. It operates as an energy absorber for the incoming waves and smooths out the wave climate. It follows that a greater amount of vegetation was seen as beneficial to the coastal strip as it reduces wave height and energy and moderates impacts on the coast.

Intertidal vegetation mapping for inlets and bays along the coast was used in this study to identify the areas of the coast that potentially benefit from intertidal vegetation. While it was understood that different types of vegetation will potentially reduce the impact of coastal processes differently, this study did not differentiate between vegetation types.

The approach applied in generating the adaptive capacity attribute relating to intertidal vegetation involved calculating the percentage cover of vegetation within 1km of each 50m coastal segment. The ratings assigned based on five broad percentage cover categories relating to intertidal vegetation is presented in Table 12.

Table 12. Intertidal Vegetation Scoring

Intertidal Vegetation Coverage	Score	Category
0 %	1	Very Low
1% – 25%	2	Low
25% – 50%	3	Moderate
50% - 75%	4	High
> 75%	5	Very High

Coastal Vegetation

Vegetation along the coastal margins, such as saltmarsh and mangroves, can also act as a coastal stabiliser and wave energy dampener. As with intertidal vegetation, vegetation along the coastal margin operates as an energy absorber for incoming waves. It can potentially stabilise the coast, holding together landscapes and preventing coastal erosion and sediment loss. Therefore, a greater amount of coastal vegetation was also viewed as beneficial.

The intertidal Ecological Vegetation Class (EVC) dataset was used to assign a score to the coastline based on the presence of Mangroves and Coastal Saltmarsh along the coast.

Ratings were assigned using a 50m proximity analysis in relation to each 50m coastal segment. The ratings assigned in this process based on the type of vegetation - mangroves or saltmarsh - are presented in Table 13.

Table 13. Coastal Vegetation Scoring

Coastal Vegetation Type	Score	Category
None	1	Very Low
Coastal Saltmarsh	3	Moderate
Mangroves	5	Very High

Coastal Adaptive Capacity – Overall Rating

An overall Adaptive Capacity rating was assigned to each 50m coastal segment based on the highest value for any of the four contributing Adaptive Capacity attributes. It was viewed that if the rating for contributing attributes were given equal weightings and an average calculated (as was the case with Exposure and Sensitivity), then the real benefits of any one factor contributing to Adaptive Capacity would be unreasonably devalued.

Figure 15 presents the overall Adaptive Capacity for the full Victorian coastline. The eastern coastlines in Gippsland were noted to have lower adaptive capacity ratings due to no reef strata, vegetative cover or engineered structures. Whereas the western shoreline in seen to have higher adaptive capacity due primarily to the benefit of reefs having a mitigative effect on the coastline.

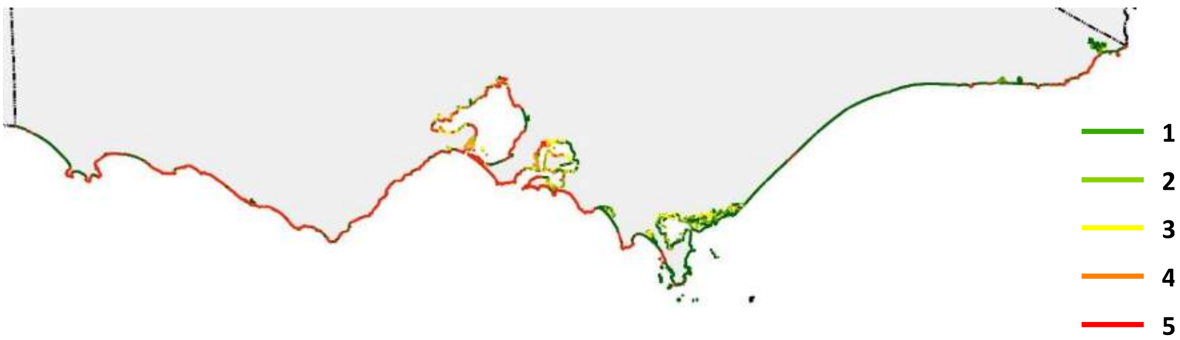

Figure 15. Map view showing Coastal Adaptive Capacity assignment Victorian coastline.

6.5 Coastal Erosion Impact Score

An overall Coastal Erosion Impact rating was generated by combining the Coastal Exposure (E) and Coastal Sensitivity (S) datasets. From these two datasets, ratings from 1 to 5 were combined by multiplying these two ratings to generate an Impact rating for each coastal segment. Scores from 1 to 25 were grouped on the basis of logical break points to provide the five Erosion rating categories presented in Table 14.

Table 14. Coastal Erosion Impact Score

Impact (Exposure x Sensitivity) Score	Category	Impact Rating
0 - 1	Very Low	1
1 - 4	Low	2
4 - 9	Moderate	3
9 - 16	High	4
16 - 25	Very High	5

Figure 16 presents this Impact Score for the full Victorian coastline. The majority of the open coast was noted to have Moderate to Very High scores, with sections of the Gippsland coastline and several exposed regions on the far west coast having the highest ratings.

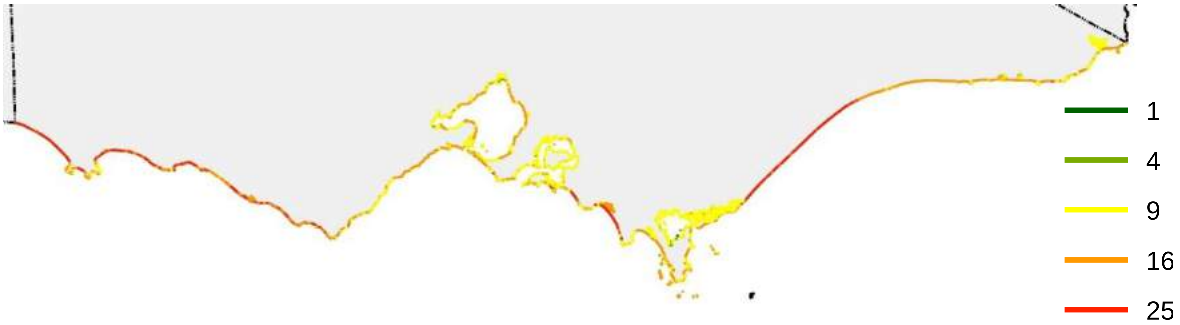

Figure 16. Map view showing Coastal Erosion Impact assignment Victorian coastline.

6.6 Coastal Erosion Vulnerability Score

A Coastal Erosion Vulnerability rating was generated by combining the Coastal Erosion Impact (I) and Coastal Adaptive (A) datasets. The outputs from both datasets, with values ranging from 1 to 25 and 1 to 5 respectively, were combined by multiplying these two ratings to generate a Vulnerability score for each 50m coastal segment. Scores from 1 to 125 were again grouped on the basis of logical break points in the data (based on the cube value of 1 to 5), to provide the five vulnerability ratings presented in Table 15.

Table 15. Coastal Erosion Vulnerability Score

Vulnerability (Impact x Adaptive Capacity) Score	Category	Vulnerability Rating
0 - 1	Very Low	1
1 - 8	Low	2
8 - 27	Moderate	3
27 - 64	High	4
64 - 125	Very High	5

Figure 17 presents this Coastal Erosion Vulnerability Score for the full Victorian coastline. One clear implication from applying the Adaptive Capacity rating to the Impact score was that the high Impact ratings in the west were reduced in terms of vulnerability in relative terms to the east coast. This was likely because of the significant area of reefs identified and used in the Adaptive Capacity rating.

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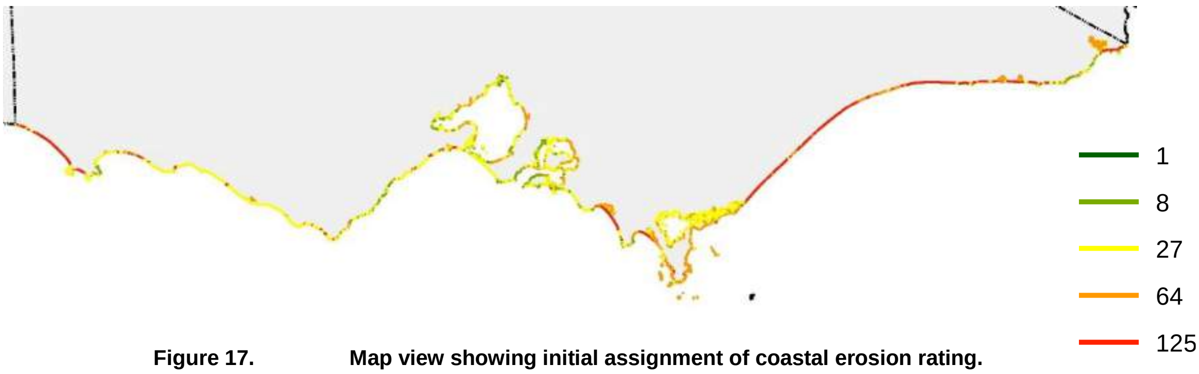

Figure 17. Map view showing initial assignment of coastal erosion rating.

Hence, the resultant Vulnerability score presents the combination of Exposure, Sensitivity and Adaptive Capacity factors as applied to individual 50m coastal segments. A general observation in relation to the results presented was that Exposure was generally greatest on the open coast, particularly south facing orientations based on prevailing storm and wind directions, and with greater stretches of open water and sharp bathymetric profiles. Sensitivity to these exposures has been greatest on sandy type shores that have a high sediment response to sea level rise where shorelines were receding. In contrast, adaptive capacity was highest along coastlines that either have a high coverage of seagrass or intertidal vegetation, a high amount of reef strata present in the nearshore environment or have some form of engineered structure.

Combined, it was generally seen that exposed open type coasts that have a sandy type shoreline with no protective factors have the greatest vulnerability to coastal erosion factors.

6.7 Assignment of Erosion Impact Rating to the Coastline

As previously noted the SmartLine dataset has been used to depict the Victorian coastline in this study, and to generate a number of coastline attributes such as fetch. While some of the attributes were directly generated using this trace of the coast, others, such as wave height and energy, require the values was other datasets to be attributed to the 50m segments of the coast. In these instances, a near analysis was performed to link the secondary input to the relevant SmartLine derived coastal segment.

6.8 Assignment of Erosion Impact Rating to Study Area

To assess the likely implications that the assessed coastal Impact and Vulnerability ratings have on coastal assets, the ratings assigned to the coastline needed to be translated to the area immediately adjacent to the coastline. This was because many of the coastal assets such as roads and built structures are often several hundred metres from the coastline.

To support this process the Coastal Erosion Vulnerability Rating and other associated ratings assigned to the SmartLine derived depiction of the coast where translated and applied across the study area. This process involved preparing and applying a 50m by 50m (2500m^2) grid cell based analysis framework for the entire study area.

The initial step in this process involved assigning the Coastal Erosion Vulnerability Rating to all cells that intersected the SmartLine derived depiction of the coast. In this process all input values used in calculating the Vulnerability score were assigned to the 50m by 50m coastal cells. Given the regular grid structure of 50m by 50m grid cells covering the study area did not exactly match with the 50m coastal segments, a majority rule was applied to assign values to coastal grid cells.

The Coastal Erosion Vulnerability Rating was then assigned to all study area cells using a near analysis process, where cells were assigned an initial 'raw' vulnerability rating on the basis of the closest (or nearest) coastal grid cell value.

Given the actual Coastal Erosion Vulnerability Rating will diminish as one moves away from the shoreline a process was developed to reduce the assigned 'raw' value using a series of rules. These rules were based around three factors that were agreed to represent a suitable basis for reducing the likely level of coastal erosion impact and vulnerability experienced as one moves away from the coast. This reduction was expressed in the form of a series of decay factors where values were reduced based on:

- Distance from the coastline
- Height above the coastline
- Land use and land cover

For distance from the coast, an inverse exponential relationship (as shown in Figure 18) was used to assign the anticipated decay from the coast on the basis of distance from the coastline, where at 1,500m from the coast a zero rating was assigned. This relationship results, for example, in a 100m change in distance close to the coast having a greater relative reduction in the assigned Coastal Erosion Vulnerability rating than a 100m change is distance significantly further from the coast.

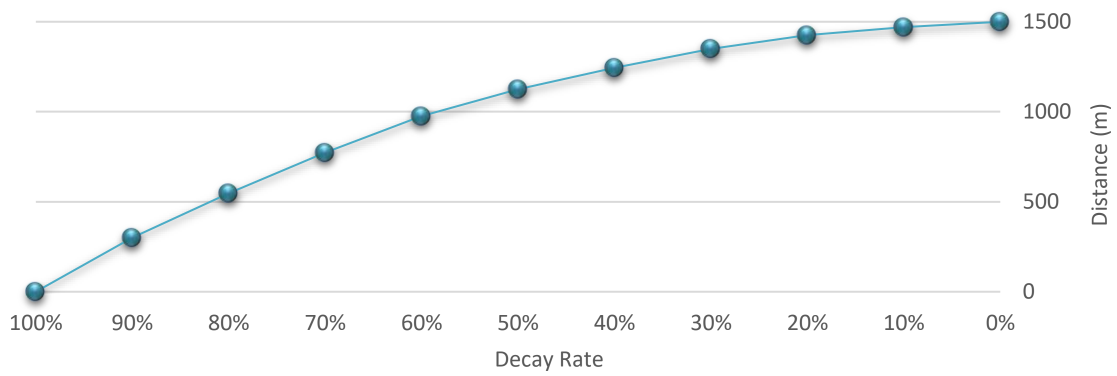

Figure 18. Inverse exponential distance decay rate, shown as decay percentage value against distance from coast.

Figure 19 provides an example of this process as assigned to areas of the Surf Coast in the Apollo Bay area. The red colour presents where 100% of the Coastal Erosion Vulnerability score was retained, while the dark green areas identify where 0% of the score, or no score, was applied.

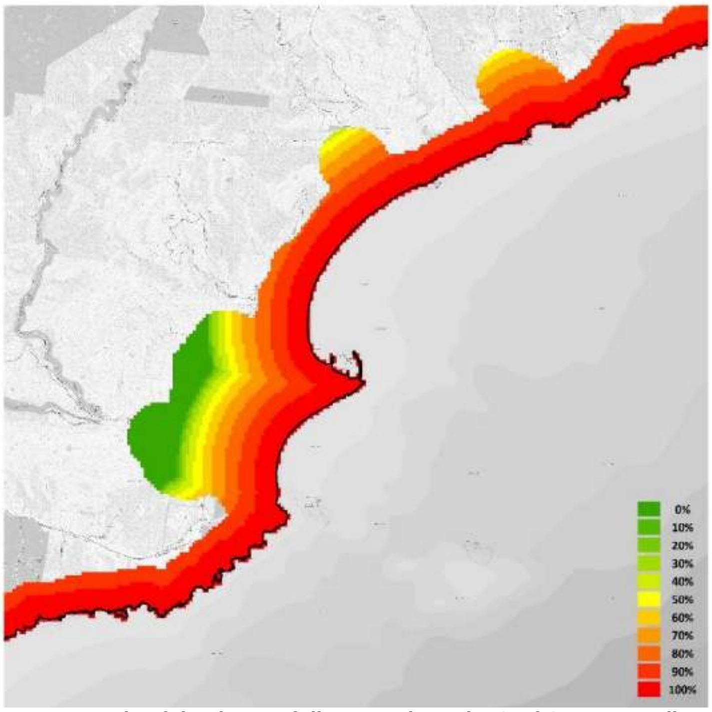

Figure 19. Example of the decay of distance along the Surf Coast coastline at Apollo Bay

For elevation, an inverse exponential relationship (as shown in Figure 20) was again used to assign the anticipated decay from the coast on the basis of the height above the coastline, where at 20m above the coast a zero rating was assigned. This relationship results in changes in elevation closest to the coast having a greater relative reduction in the assigned Coastal Erosion Vulnerability rating than those significantly above the coast.

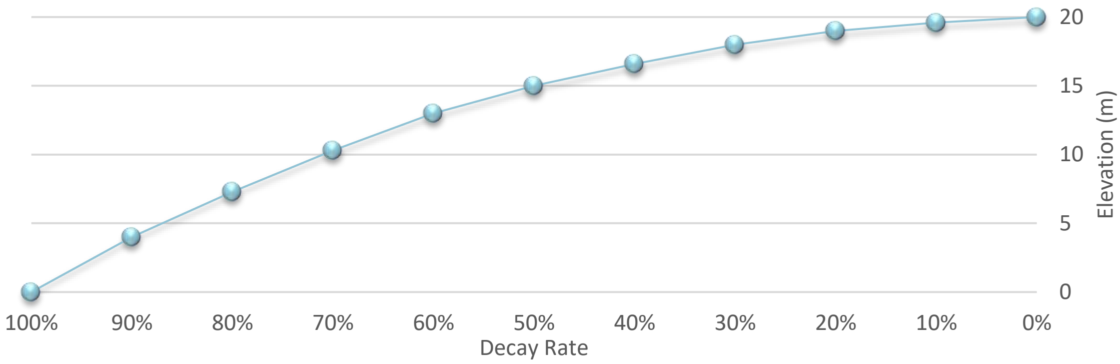

Figure 20. Inverse exponential elevation decay rate, shown as decay percentage value against elevation above sea level.

Application of this process involved using a 20m resolution elevation model to initially attribute 50m by 50m grid cells based on a simple majority elevation assessment. This process also involved assigning a height to any Coastal Engineered Structure on the coast where the structure height was known.

Figure 21 presents a representation of this decay process for a region along the Surf Coast near Apollo Bay. The red colour presents where 100% of the Coastal Erosion Vulnerability score was retained, while the dark green areas identify where 0% of the score was applied. This figure shows how the cliff areas in the south and north significantly restrict the potential influence of coastal erosion away from the coast, while the flatter areas around Apollo Bay and river valleys are likely to experience a greater level of impact further inland.

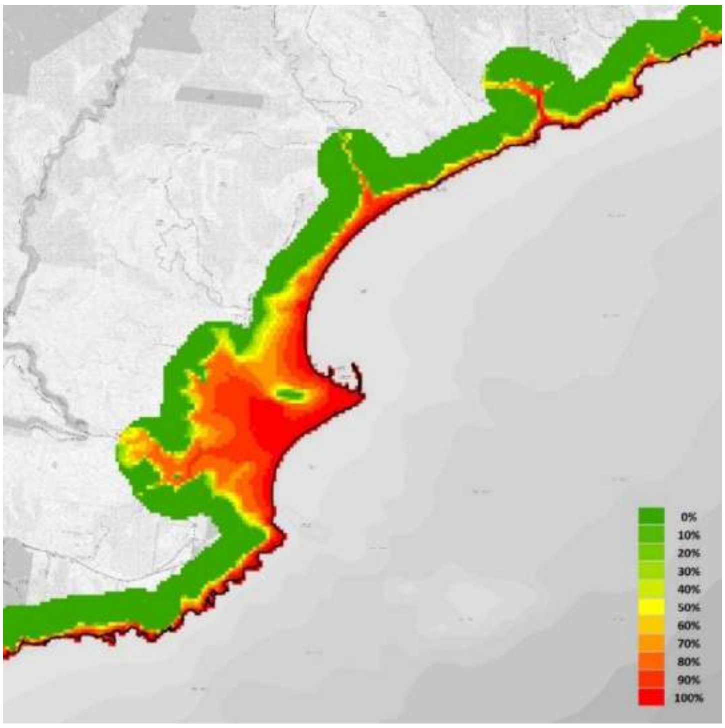

Figure 21. Example of the decay of elevation along the Surf Coast coastline at Apollo Bay

Different types of land cover and land use were also expected to influence the way coastal erosion impacts on areas away from the coast. This study took the view that more natural land uses and cover would provide more resilience to coastal erosion in comparison with built environments or bare ground. Hence, different decay rates were applied to the raw Coastal Erosion Vulnerability rating on this basis.

Land cover and land use classes were assigned to study area grid cells on a majority basis using the Victorian Land Use Information System (VLUIS) dataset. Several other datasets including plantation and tree cover layers were considered, but were not pursued due to observed inconsistencies in coverage.

The decay factors applied based on land cover and land use were as follow:

- Native vegetation assigned a 30% decay
- Non-Native woody vegetation assigned a 20% decay
- Disturbed, Bare Ground or Farm-Land assigned a 10% decay
- Built-up environment, Urban assigned a 0% decay

Figure 22 presents a representation of these decay factors for a region along the Surf Coast near Apollo Bay. The gold colour presents where 100% of the Coastal Erosion Vulnerability score was retained in built up areas, while the pink areas identify where 70% of the score was applied for areas containing significant native vegetation cover.

This decay component results in built-up or urbanised land having no significant impact on alleviating coastal erosion, while for some areas of the coast the presence of built coastal protection structures have a positive impact in reducing coastal erosion. The value of coastal protection structures was accounted for and modelled in the adaptive capacity attributes.

Similarly, natural coastal vegetation, such as mangroves, was also accommodated in the process used to assign an adaptive capacity rating. However, the adaptive capacity modelling was only assigned to the coast, while the decay modelling applied to the vulnerability score was assigned across the entire study area.

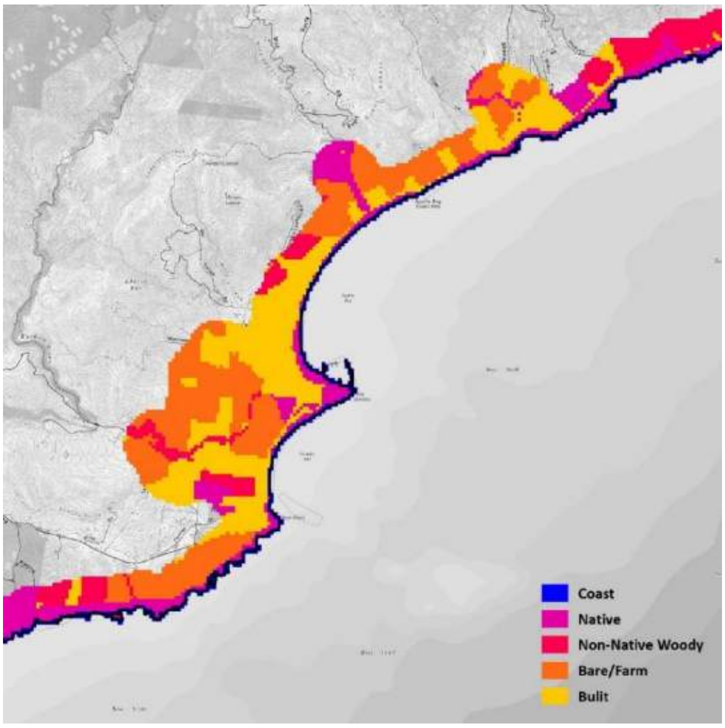

Figure 22. Example of the decay of land cover along the Surf Coast coastline at Apollo Bay

7. Coastal Inundation Rating - Method

Coastal inundation impacts for the study area were considered and attributed across the spatial extent of the study area using datasets that provided:

- Anticipated Sea Level Rise (SLR) for years 2040, 2070 and 2100
- Anticipated Storm Surge (STM) for years 2040, 2070 and 2100
- Modelled extent of 1 in100 year flood events
- Presence of Coastal Acid Sulphate Soils (CASS)

For each of these four factors, the presence or absence of their mapped extent or impact were scored back into the study area 50m by 50m grid cells. This information was used to assess the likely impact of inundation related factors on coastal assets.

Data Inputs

Sea Level Rise and Storm Surge

The Victorian Coastal Inundation Dataset was used as the key input into the anticipated SLR and STM, to define inundation extents. This dataset presents eight spatial layers that depict the modelled extent of land likely to be subject to inundation due to projected SLR from 2009 to 2100. The base SLR for 2009 was a 0cm increase, for 2040 a rise of 20cm is anticipated, for 2070 a rise of 47cm, and for 2100 a projected rise of 82cm. The STM layers were equivalent to a 1 in 100 year storm tide. The STM extents use the projected SLR increases for the corresponding year plus an additional wind forcing factor. For 2009 this was a 0% forcing, 2040 applies a 6% forcing (on the 20cm), 2070 a 13%, and 2100 applies a 19% forcing plus on the anticipated 82cm SLR level increase.

All SLR and STM modelled extents have been generated using a fill-type model, where any projected increases were modelled against an elevation base layer to determine inundation extents.

Flood Events

The modelled extent of 1 in 100 year flood events was sourced from the Victorian Flood Database. This database contains multiple layers for different time scales of flood events ranging from 1 in 5 year to 1 in 1000 year flood events. The database contains both modelled and observed data for these flooding extents. This study adopted the extent of 1 in 100 year flood events given the use of this time scale in general land management and planning work, including flood overlays. The 1 in 100 year data used, incorporates both modelled and observed flood event extents.

Coastal Acid Sulphate Soils

The distribution of CASS in the study area was based on the Coastal Acid Sulphate Soils layer available from DELWP. This spatial data layer represents coastal areas that contain potential CASS affected soils. This dataset was based on either modelled or observed data for these soils.

Application to the Study Area

The presence or absence of SLR, STM, Flood and CASS was assigned to each 50m by 50m grid cell across the study area. For SLR and STM, this involved a simple attribution of presence or absence to a grid cells. Multiple record fields were used for each of the available timeframes for SLR and STM.

Figure 23 presents two views of the Port Phillip and Westernport, with projected SLR in blue and STM in purple. The view in the left panel presents the modelled data for 2040 (corresponding to anticipated SLR of 20cm), and the right panel modelled data for 2100 (corresponding to anticipated SLR of 87cm).

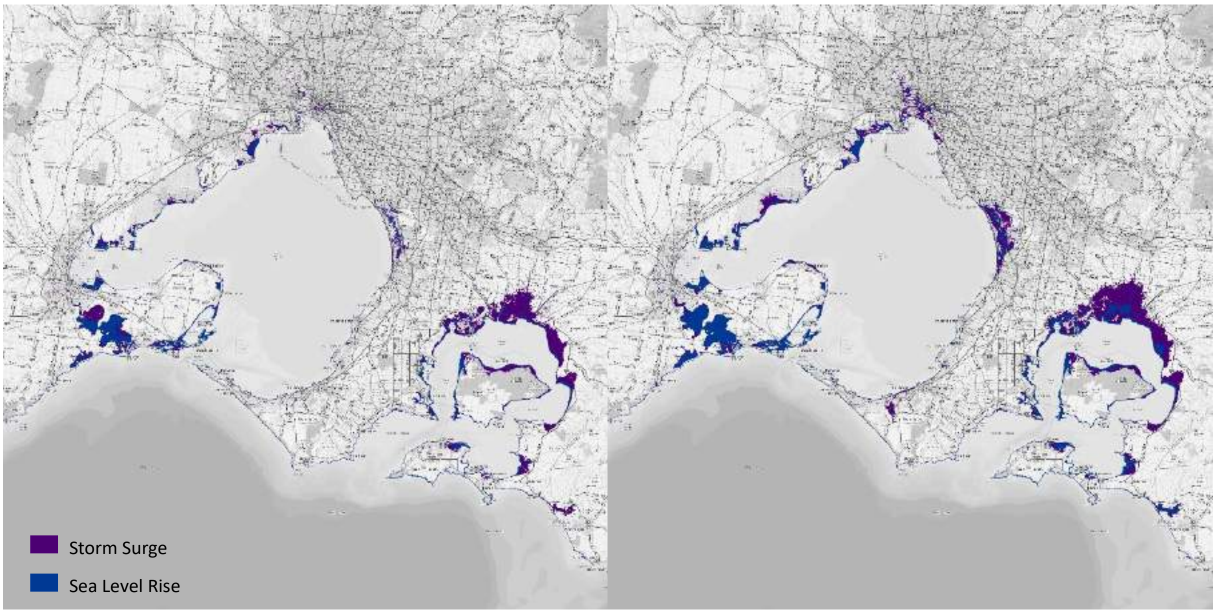

Figure 23. Sea Level Rise and Storm Surge in the Port Phillip and Westernport Bay Regions, presenting anticipated change in 2040 – 20cm (left panel), and 2100 – 87cm (right panel).

Flood events occur from inland water sources such as rivers and other water bodies transferring water into coastal regions. As an initial step each 50m by 50m grid cells was assigned a presence or absence rating in relation to the 1 in 100 year flood extent dataset. However, given this was a static dataset, in that it did not account for anticipated SLR over time, as projected sea level rises encroach on the land, it was recognised that the flood event coverage depicted has reduced over time. Therefore, for each of the timeframes from 2040 to 2100, the land area impacted by 1 in 100 year flood events has become less based on projected SLR.

The process of attributing the 1 in 100 year flood event information in vector format into the study area grid cells of 50m resolution involved using a presence or absence approach.

As a final step the influence of SLR in each timeframe on a grid cell identified to be also impacted by a 1 in 100 year flood event was suitably attributed for modelling purposes.

Figure 24 depicts in the left panel, the 1 in 100 year flood events for the Port Phillip and Westernport Bay region. These areas were constrained to lower elevation areas, river valleys and inlets. In coastal regions they also correspond with areas known to experience STM events or projected SLR.

A key consideration in assessing the distribution and proximity of Coastal Acid Sulphate Soils to coastal assets was the relationship between these soils and flooding and inundation events given that these soils produce sulphuric acid during wetting and drying events. Hence, for CASS a two stage process was used to attribute grid cells, where first the presence or absence of CASS was assigned to a grid cell, and second, whether the grid cell was likely to be impacted by a flood or storm tide event that has activated the CASS in the soil profile.

The right panel in Figure 24 presents the extent of activated CASS soils across the Port Phillip and Westernport Bay regions. As anticipated there was significant alignment between the distribution of areas likely to be subject to flood events and activated CASS areas as a result of flood or STM events.

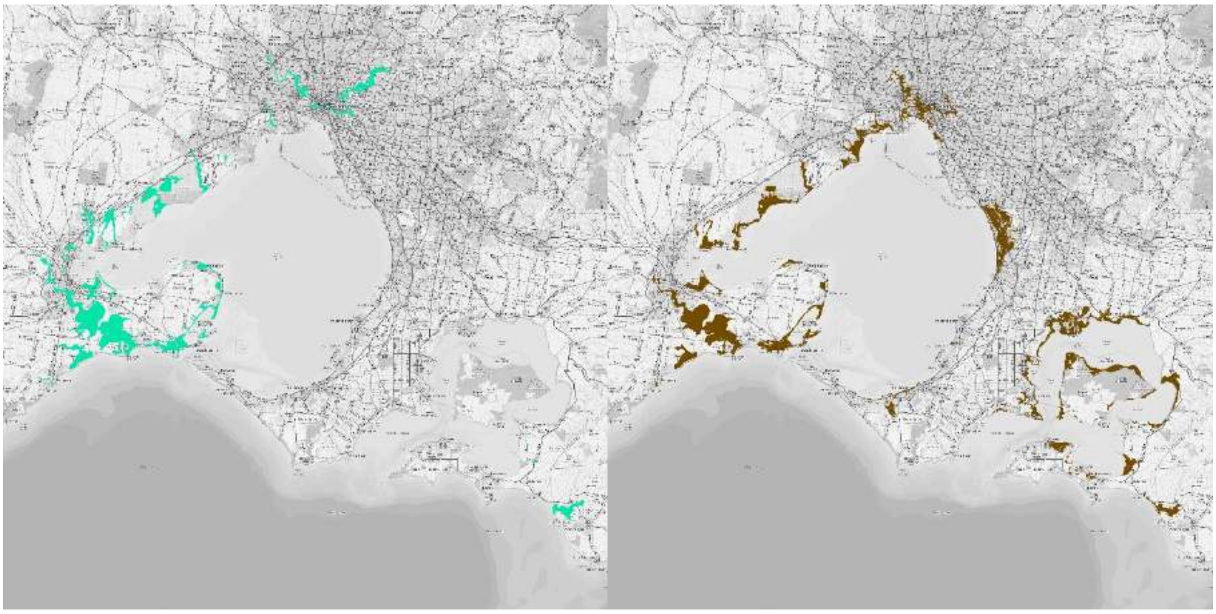

Figure 24. 1 in 100 year Flood Event (left panel) and Coastal Acid Sulphate Soils (right panel) in the Port Phillip and Westernport Bay Regions.

The approach used to assign inundation impacts to coastal assets, as outlined in this section, applies a limited timeframe component.

While SLR and STM were modelled based on anticipated change corresponding with the years 2040, 2070 and 2100, the 1 in 100 year flood extents were non-time specific, but rather, represent an extreme event scenario based on current sea levels. Similarly, the distribution of CASS impacted areas uses a combination of some timeframe elements based around STM events, in addition to flood event scenarios based on current sea levels.

PART 3 – ASSETS CONSIDERED

8. Coastal Assets Assessed

8.1 Introduction

This study required an assessment of the likely impacts of anticipated climate change on coastal assets. Hence, assets along the coast were broadly identified based on a review of previous studies and existing spatial datasets. These assets could either be directly related to or adjacent to the coast, such as beaches or surf lifesaving clubs, or they could be located some distance from the coast such as the Great Ocean Road or selected built structures, but still vulnerable to coastal erosion and inundation.

Assets identified from available reports and literature were broadly grouped into triple bottom line groups on the basis of the service they provided with the coast itself identified as a forth group. Hence, the following four coastal broad asset types identified were:

- Coast
- Economic
- Social/Cultural
- Environmental (natural assets)

These asset types were expected to overlap, with some assets identified in more than one asset type group. While the entire coastline was assigned a coastal classification type, specific assets along the coast were represented in different formats. For example, camping grounds and yacht clubs were identified using point locations, while others, such as roads, were identified as linear features, and larger area based features, such as the extent of seagrass or RAMSAR classified wetlands, represented as polygons.

In addition to reviewing the conceptual framework to be applied in this impact assessment, a key area that needed to be addressed along with decisions concerning the framework was the classification system applied to differentiate and delineate assets. This delineation needed to be at a suitable level so as to assign a value rating to coastal assets.

8.2 Asset Identification and classification

Coastal assets needed to be spatially delineated and meaningfully defined for the purposes of assessing the likely impact of anticipated climate change in terms of coastal erosion vulnerability and inundation.

For this project, the level at which asset erosion and inundation ratings were assigned, was termed the Asset Category level. This Asset Category was the level at which an asset was spatially delineated for the purposes of assigning potential climate change impacts and vulnerability. The Asset Category was to be viewed in terms of an asset classification system or hierarchy where the Asset Groups, Asset Classes, and Asset Sub-classes were also identified.

An example of this classification hierarchy, as applied to a power station, is presented in Figure 25.

Using this asset classification schema, assets grouped into the four identified broad Asset Types were further differentiated into seven asset classes comprising twenty-five asset sub-classes. Within these sub-classes a large number of asset categories were identified. A full listing of assets identified for the Victorian coastal area using this schema is presented in **Appendix 7**.

While this classification of coastal assets was used to assign project findings, it was not used to assess coastal erosion and inundation for an individual Asset Category as originally proposed. It had been intended that individual Asset Categories themselves would be assigned a sensitivity rating and adaptive capacity rating. This approach was not pursued on the basis it was agreed the preferred approach was apply sensitivity and adaptive capacity ratings directly to the coast and then to assets based on their proximity and relationship to the coast.

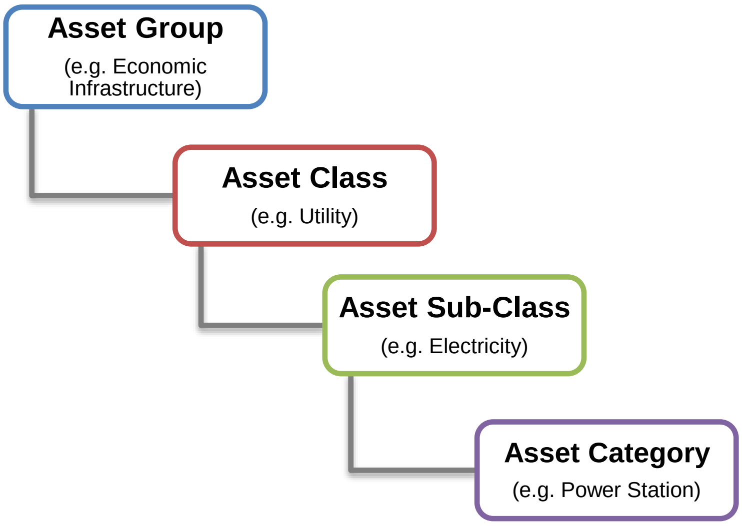

Figure 25. Asset grouping and classification schema.

8.3 Approach for different asset types

Coastal assets could be spatially represented as a point, line or polygon feature. Further to this, for lines and polygons, both length and area, respectively, could be determined based on their footprint in the study area.

In assigning the implications of assessed likely coastal erosion and inundation impacts for assets represented as different spatial features, different approaches were required to determine coastal asset based scores.

Point

For assets represented as point features, assets were assigned a score based the 50m by 50m grid cell they were located within. Further to this, a selection of adjacent cells within a search radius of 25m was applied and included to provide an overall asset score. In using this approach, not only was the immediate grid cell considered, but also the surrounding cells that were viewed to have a potential influence on the site are also included.

Line

For assets represented as line features, the scores of all grid cells that the line interests or falls within were used. No majority or proportional rules were applied for this selection process, only whether a section of a line falls within a cell or not.

The length of the asset, in kilometres (km) was also recorded, where the full length of the asset over the entire study area and the sectional length within a given coastal sediment compartment, was identified.

Polygon

For assets represented as polygon features, the scores of the cells that the polygon footprint intersects with were used. Again, no majority or proportional rules were applied in this selection process.

The area of the asset, in hectares (ha), was also recorded, where both the full area of the asset over the entire study area and the sectional area within a given sediment compartment, was identified.

8.4 Data Sources

The spatial features representing a coastal asset were sourced from one or more spatial datasets. Where possible, one layer and one feature type (point, line, polygon) was used, although where necessary two or more layers were used to generate a single asset category dataset. This section provides a brief description of the key data sources used to depict coastal assets.

The majority of asset spatial representations were obtained from the VicMap Features of Interest point, line or polygon feature class layers. This is a regularly updated dataset that contains points of interest such as education facilities, landmarks and power utilities. This spatial data layer describes the feature, location and name, where available.

Heritage boundaries and overlays were sourced through the Victorian Planning Scheme Overlay. Other heritage related datasets, such as the Register of the National Estate, were sourced from the relevant government organisations.

For natural assets, park boundaries and reserves, the Public Land Management (PLM) layer was used to obtain relevant national and state park boundaries. Beaches and foreshores were sourced from a derived Crown land layer, which was based on the PLM layer. Wetlands were obtained from the Victorian Water Asset Database, which was used to describe all Victorian water bodies, such as reservoirs, including wetlands. RAMSAR sites were sourced separately from the RAMSAR Wetland Areas data layer.

Road, train and other transport link utilities were sourced from relevant Vicmap spatial layers relating to those utilities.

A full list of data sources used to spatially represent assets is presented in **Appendix 5**: Data Sources. This list identifies whether a single dataset or multiple sources were used for a given asset category.

8.5 Parameters identified

For each asset, a standard set of attributes relating to coastal erosion and inundation were generated. Each asset was initially assigned to one or more coastal (secondary level) sediment compartments, and assigned a quantity: length in km (for line features); area in ha (for polygon features); or area of influence (for point features). For assets represented as a point feature, the area of influence was used for further calculations.

For Coastal Erosion, the parameters identified were:

- Quantity of asset impacted by High and Very High coastal erosion vulnerability rating.
- Percentage of asset impacted by High and Very High coastal erosion vulnerability rating.

For Inundation, for the years 2040 and 2100 representing a 20cm and 82cm SLR respectively, the parameters identified were:

- Quantity of asset impacted by SLR, STM, Flood and CASS activation with STM/Flood combination.
- Percentage of asset impacted by SLR, STM, Flood and CASS activation with STM/Flood combination.

8.6 Asset significance

A key consideration in this study was the relative importance of a particular asset. Given the large number of assets along the coast it was viewed as a critical step to focus and report on assets viewed to be of greatest value.

The scoping and literature review of previous coastal studies identified that some studies had applied asset classifications that assigned levels of significance or importance to assets based on their function, location or level or service.

It was agreed that for this study the assignment of a significance rating to assets would be based on existing classification schemas, or existing asset attributes where possible. The coastal assets of particular note were those already assessed to be of significant value by DELWP at the regional, state, national and international level (as described in the next section). Worked examples of the proposed set of attributes relating to coastal erosion and inundation for a selected cross-section of these assets were prepared prior to the application of the proposed assessment method to a broader group of coastal assets.

Priority Assets

Assets identified and delineated by DELWP in a 2015 Coastal Climate Change Risk Assessment (DELWP, 2015) are presented in general terms in Figure 26.

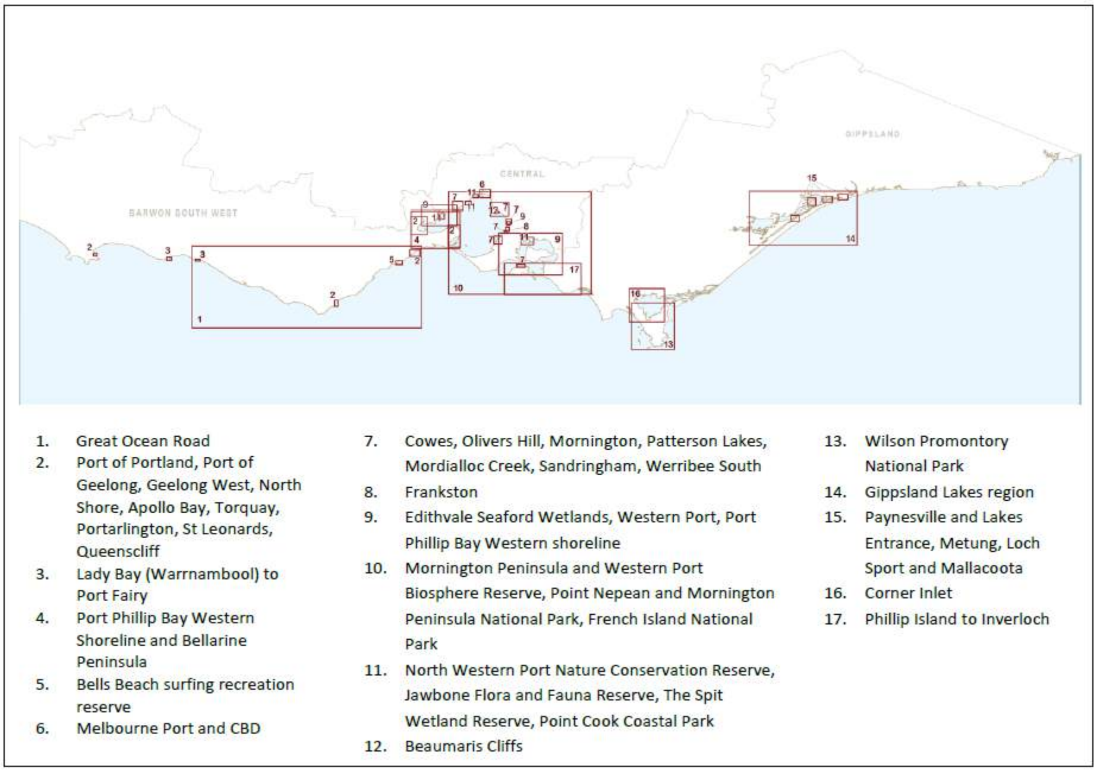

Figure 26. Coastal assets assessed relevant to DELWP and of regional, state, national or international significance.

Source: DELWP Coastal Climate Change Risk Assessments (2015)

This assessment identified 21 significant coastal assets across three coastal regions Barwon South West, Central and Gippsland zones. These assets together with the rationale behind their significance are presented in Table 16. The table identifies how the assigned priority rating was based on levels of significance ranging from an international to a local scale.

Table 16. DELWP Priority Assets

Priority Asset	Significance
Barwon South West	
Great Ocean Road	• Australian Natural Heritage site • Nationally significant Tourist destination • Regionally significant tourist destination • Nationally significant landscape • State significant landscape
Port of Portland, Port of Geelong, Geelong West, North Shore, Apollo Bay, Torquay, Portarlington, St Leonards, Queenscliff	• Asset/utility of national importance • Regional Boating facilities • Regionally strategic port and harbour
Lady Bay (Warrnambool) to Port Fairy	• State marine precinct • Regional Boating facilities • Regionally significant landscape

Priority Asset	Significance
Great Otway National Park	• National Park • Natural Resource Area of Significance
Discovery Bay Coastal Park	• State significant landscape • Regionally significant landscape • Coastal Park
Port Phillip Bay Western Shoreline and Bellarine Peninsula	• RAMSAR listed wetland • Significant Open Space
Bells Beach Surfing Recreation Reserve	• Victorian heritage register • Nationally significant landscape
Central	
Melbourne Port and CBD	• Integrated economic triangle • State Boating precinct • Internationally significant Tourism destination
Port of Hastings	• Integrated economic triangle • State Boating precinct
Cowes, Olivers Hill, Mornington, Patterson Lakes, Mordialloc Creek, Sandringham, Werribee South	• Regional Boating precincts
Frankston	• Metropolitan activity centre
Edithvale Seaford wetlands, Western Port, Port Phillip Bay Western Shoreline	• RAMSAR listed wetland • Significant Open Space
Mornington Peninsula and Western Port Biosphere Reserve, Point Nepean and Mornington Peninsula National Park, French Island National Park	• UNESCO Biosphere Reserve • National Park • Significant Open Space
North Western Port Nature Conservation Reserve, Jawbone Flora and Fauna Reserve, The Spit Wetland Reserve, Point Cook Coastal Park	• National Park • Significant Open Space
Beaumaris Cliffs	• Site of International geological and geomorphological significance • Register of National Estate
Gippsland	
Wilson Promontory National Park	• State significant Tourist destination • UNESCO Biosphere Reserves • State significant landscape • National Park
Gippsland Lakes region	• State significant Tourist destination • RAMSAR listed wetland • Nationally significant wetlands • National Park • State significant landscape • Regionally significant landscape
Paynesville and Lakes Entrance, Metung, Loch Sport and Mallacoota	• State level boating facilities • Regional level boating facilities
Corner Inlet	• RAMSAR listed wetland • Regionally significant landscape • Marine National Park
Croajingolong National Park	• State significant landscape • UNESCO Biosphere Reserves • National Park
Phillip Island to Inverloch	• State significant Tourist destination • State significant landscape • Regionally significant landscape • Nationally significant wetlands

Further to this, for each significance reference attributed to each Priority Asset, an overall significance rating was assigned, as outlined in Table 17. This rating was principally based on the significance in terms of the scale at which it was viewed to represent on a scale from international to local.

Table 17. DELWP Priority Asset significance ratings

SIGNIFICANCE	SIGNIFICANCE LEVEL	SIGNIFICANCE ID
RAMSAR listed wetland	International	1
UNESCO Biosphere	International	
Geological and geomorphological site	International	
Tourism	International	
Asset/utility of national importance	National	2
National Park	National	
Wetlands	National	
Natural Heritage site	National	
Register of National Estate	National	
Tourism	National	
Landscape	National	
Marine precinct	State	3
Boating facilities	State	
Heritage register	State	
Landscape	State	
Tourism	State	
Strategic port and harbour	Regional	4
Boating facilities	Regional	
Tourism	Regional	
Landscape	Regional	
Open space	Local	5
Integrated triangle	Local	
Metropolitan Activity Centre	Local	

This DELWP Priority Asset classification includes many of the asset categories previously identified using the triple bottom line categories of economic, environmental and social/cultural.

High Value Assets

Stakeholders expressed concern over a number of other higher value assets within the study area. These high value assets overlap with many of those identified within the DELWP Priority Asset listing and include:

- Residential Property
- Commercial property
- Surf Life Saving Clubs & linked beaches
- Key beaches
- Camping grounds
- Caravan Parks
- State/Regional Boating Facilities
- Major piers and jetties
- Critical infrastructure – power, gas, water treatment
- Critical services – communication, police, hospital, fire

8.7 Assignment of Erosion and Inundation Rating to Coastal Assets

The assignment of coastal erosion and inundation ratings to significant coastal assets on a sediment compartment basis was undertaken using spatial analysis tools. This process generated a standardised report or profile for each asset that provided both absolute asset quantity values and percentage breakdowns for each attribute category.

The profile provided a summary of the full erosion impact ratings for an asset. For example, in relation to coastal erosion, while ratings from very low to very high were obtained, the profile only presented a combination of high and very high scores. For inundation, while results were obtained for the years 2040, 2070 and 2100, the results for 2070 were not included in the standard asset profile.

An example of the asset profile report generated for an asset represented as a polygon feature is presented in Table 18. The table identifies both the total area the asset footprint occupied within the study area and the portion of this area that was considered land only. It was noted that some asset categories, such as Marinas or Ports, occupied some area identified as water in the study.

Table 18. Example output report for polygon feature type asset

Compartment	Feature Type	Unit	Quantity Total	Quantity Land	H/VH	2040 SLR	2100 SLR	2040 STM	2100 STM	2040 Flood	2100 Flood	2040 CASS	2100 CASS
Compartment Name - XXXXX													
Asset A	Polygon	Ha	60.16	60.16									
Quantity					18.05	48.9	48.58	51.81	49.5	0	0	4.94	4.85
Percentage					30.01%	81.27%	80.74%	86.11%	82.27%	0.00%	0.00%	8.21%	8.06%
Asset B	Polygon	Ha	5.05	1.08									
Quantity					5.05	3.37	5.05	4.21	5.05	0	0	3.37	3.37
Percentage					100.00%	66.67%	100.00%	83.33%	100.00%	0.00%	0.00%	66.67%	66.67%
Asset C	Polygon	Ha	4556.61	4546.94									
Quantity					18.89	439.34	846.95	882.79	1000.01	0	0	722.7	837.99
Percentage					0.41%	9.64%	18.59%	19.37%	21.95%	0.00%	0.00%	15.86%	18.39%

An example of the asset profile report generated for an asset represented as a line feature is presented in Table 19. Again, some asset categories, such as Jetties or Wharfs, were identified to occupy some area of water.

Table 19. Example output repot for line feature type asset

Compartment	Feature Type	Unit	Quantity Total	Quantity Land	H/VH	2040 SLR	2100 SLR	2040 STM	2100 STM	2040 Flood	2100 Flood	2040 CASS	2100 CASS
Compartment Name - XXXXX													
Asset A	Line	Km	45.86										
Quantity					29.07	19.79	22.84	30.25	28.42	0	0	1.27	1.22
Percentage					63.40%	43.15%	49.80%	65.95%	61.96%	0.00%	0.00%	2.76%	2.66%
Asset B	Line	Km	87.78										
Quantity					61	39.48	44.56	56.41	51.15	0	0	10.65	10.34
Percentage					69.50%	44.97%	50.76%	64.26%	58.27%	0.00%	0.00%	12.13%	11.78%
Asset C	Line	Km	0.71										
Quantity					0.71	0	0.16	0	0.16	0	0	0	0
Percentage					100.00%	0.00%	22.22%	0.00%	22.22%	0.00%	0.00%	0.00%	0.00%

An example of the asset profile report generated for an asset represented as a point feature is presented in Table 20. This output was nearly identical to that for a polygon feature except that the hectare amounts were based on the results for the immediate grid cell in which the point feature was located and cells within a 25m search radius.

Table 20. Example output repot for point feature type asset

Compartment	Feature Type	H/VH	2040 SLR	2100 SLR	2040 STM	2100 STM	2040 Flood	2100 Flood	2040 CASS	2100 CASS
Compartment Name - XXXXXX										
Asset A	Point									
Quantity		1	0	0	0	0	0	0	0	0
Percentage		100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Asset B	Point									
Quantity		0	0.25	0.25	0.25	0.75	0	0	0.25	0.75
Percentage		0.00%	25.00%	25.00%	25.00%	75.00%	0.00%	0.00%	25.00%	75.00%
Asset C	Point									
Quantity		0.75	0.25	0.5	0.5	1	0	0	0.5	1
Percentage		75.00%	25.00%	50.00%	50.00%	100.00%	0.00%	0.00%	50.00%	100.00%

PART 4 – PROJECT FINDINGS

9. Project Findings

9.1 Introduction

Initial applications of the Coastal Erosion Vulnerability rating and Inundation Factors were applied to the coastline and then to the full study area. For ease of processing and for ease of communication the analysis was further broken into the 23 Victorian secondary level coastal sediment compartments.

Coastal erosion and inundation information was then applied to coastal assets within the study area. Potential coastal assets were identified based on a review of various studies, reports and literature, and were broadly identified as part of the coastline itself, or grouped into assets that provide an economic, social/cultural or environmental service or function.

Four broad asset types identified were:

- Coast
- Economic
- Social
- Environmental (natural)

A large number of assets were identified within the coastal areas, from assets that provide important functions such as power plants or boating facilities, to those that are of minor importance.

DELWP has previously identified a large sub-set of Priority Assets that hold significance across a range of scales, from international to local, as well as holding significance based on their economic, social and environmental importance.

Also of consideration were other high value assets that provided a significant level of service ranging from a state to a local population. This included assets such as beaches, surf lifesaving clubs, camping sites, power plants, water treatment plants and communication facilities.

9.2 The Victorian Coast – Overview of Coastal Erosion Ratings

Initial findings were presented for the coastline as a whole. Table 21 shows a breakdown of coastal erosion ratings assigned to the coastline for the entire coastline and for each sediment compartment.

The majority of the Victorian coastline was scored to have a moderate rating. Just over one third was assessed to have a high to very high rating. The sediment compartments with higher erosion ratings were found to occur along the eastern coastline, and included Wilsons Promontory, Gippsland Lakes and Cann River. Some western compartments, including Discovery Bay and Torquay, were also found to have high ratings. Embayments and sheltered coastlines tended to have moderate to lower ratings.

Some of the coastal strips assessed to have a high rating were those more closely associated with natural coastlines that are relatively isolated and often related to National Parks or coastal reserves.

Sediment compartments with more urbanised or sheltered coastal strips, such as Port Phillip Bay, were found to have lower coastal erosion vulnerability ratings. These areas typically have lower coastal erosion vulnerability ratings due to engineered structures protecting urban assets, or sheltered inlets having higher concentrations of intertidal vegetation.

Table 21. Full Coastline Sediment Compartment breakup showing total length and High and Very High Coastal Erosion Vulnerability ratings.

Compartment			Very Low	Low	Moderate	High	Very High
Full Coast							
	Km	4,094.69	0.00	341.30	2,300.02	1,051.75	401.61
			0.00%	8.34%	56.17%	25.69%	9.81%
1. Discovery Bay							
	Km	49.61	0.00	0.55	40.01	9.05	46.75
			0.00%	0.57%	41.52%	9.39%	48.52%
2. Portland Bay							
	Km	110.58	0.00	6.05	88.74	15.80	10.75
			0.00%	4.99%	73.13%	13.02%	8.86%
3. Warrnambool							
	Km	97.64	0.00	0.30	92.56	5.35	4.41
			0.00%	0.29%	90.19%	5.22%	4.30%
4. Port Campbell							
	Km	123.31	0.00	0.00	110.87	12.45	7.80
			0.00%	0.00%	84.56%	9.49%	5.95%
5. Great Ocean Road							
	Km	121.91	0.00	6.70	105.71	9.75	4.60
			0.00%	5.29%	83.39%	7.69%	3.63%
6. Torquay							
	Km	66.96	0.00	0.80	55.96	10.30	10.80
			0.00%	1.03%	71.87%	13.23%	13.87%
7. Port Phillip Bay Mouth							
	Km	0.00	0.00	0.00	0.00	0.00	0.00
			0.00%	0.00%	0.00%	0.00%	0.00%
8. Port Phillip Bay West							
	Km	235.91	0.00	15.27	154.17	67.03	1.60
			0.00%	6.41%	64.76%	28.16%	0.67%
9. Port Phillip Bay East							
	Km	193.25	0.00	12.85	123.70	56.70	13.55
			0.00%	6.21%	59.82%	27.42%	6.55%
10. Nepean Peninsula							
	Km	50.58	0.00	6.85	43.73	0.00	0.00
			0.00%	13.54%	86.46%	0.00%	0.00%
11. Cape Schank Flinders							
	Km	36.90	0.00	7.45	29.46	0.00	0.00
			0.00%	20.18%	79.82%	0.00%	0.00%
12. Western Port							
	Km	392.71	0.00	44.85	243.35	104.51	0.20
			0.00%	11.41%	61.94%	26.60%	0.05%
13. Phillip Island South							
	Km	57.76	0.00	8.46	47.47	1.83	1.75
			0.00%	14.22%	79.76%	3.07%	2.94%
14. Cape Woolamai Cape Paterson							
	Km	61.06	0.00	5.81	50.26	4.99	0.35
			0.00%	9.45%	81.85%	8.13%	0.57%
15. Venus Bay							
	Km	128.18	0.00	4.76	44.34	79.08	25.75
			0.00%	3.09%	28.81%	51.37%	16.73%
16. Waratah Bay							
	Km	125.59	0.00	6.00	58.16	61.43	14.46
			0.00%	4.29%	41.53%	43.86%	10.32%
17. Wilsons Promontory Southwest							
	Km	72.36	0.00	1.15	8.31	62.90	3.95
			0.00%	1.51%	10.89%	82.43%	5.18%
18. Wilsons Promontory East							
	Km	93.58	0.00	2.05	14.14	77.39	11.75
			0.00%	1.95%	13.42%	73.47%	11.16%

Compartment		Very Low	Low	Moderate	High	Very High
19. Corner Inlet						
Km	713.25	0.00	6.95	480.52	234.84	19.58
		0.00%	0.94%	64.77%	31.65%	2.64%
20. Gippsland Lakes						
Km	638.36	0.00	185.51	383.84	72.12	107.40
		0.00%	24.77%	51.26%	9.63%	14.34%
21. Snowy River						
Km	14.76	0.00	0.65	3.40	10.71	46.91
		0.00%	1.05%	5.51%	17.36%	76.07%
22. Cann River						
Km	84.67	0.00	5.77	38.58	40.37	46.76
		0.00%	4.39%	29.34%	30.71%	35.56%
23. Mallacoota Inlet						
Km	210.44	0.00	12.53	82.75	115.16	22.50
		0.00%	5.38%	35.53%	49.44%	9.66%

9.3 Compartment Findings

In contrast to assessing the coastal erosion rating to the coastline, inundation factors were assessed in relation to the inland study area. Study area boundaries could extend a considerable distance inland due to the use of the 10m contour lines and a 500m buffer. Similarly, when the coastal erosion vulnerability rating assigned to the coastline was applied to the study area using distance, elevation and land cover decay factors, significant portion of the study area was assigned a coastal erosion vulnerability rating. Large areas as expected were also assigned a coastal erosion rating of zero.

Table 22 presents the areas impacted by inundation factors of SLR, STM, Flood and CASS for 2040 and 2100 for each sediment compartment. The table identifies the full compartment area including all intertidal and land based areas, including the portion of land area subject to each inundation factor.

All sediment compartments were identified to experience some form of inundation related event. Sea level rise and storm surge events by 2040 and 2100 were noted to occur in compartments that have significant areas of low elevation. This was prevalent in the Torquay, Corner Inlet and Gippsland Lakes compartments where large areas are below the 20m elevation contour. Others, such as Warrnambool and Port Campbell, were not too prone to SLR due to higher coastal elevations.

Flood event coverages were noted to decrease from 2040 to 2100. This was due to SLR in the latter timeframes reducing the amount of land that could become flooded, since it was already covered in water. Most flooding was identified in those compartments with major inlets or rivers. Warrnambool, Port Campbell, Gippsland Lakes and Snowy River compartments showed the greatest areas affected by flooding events due to major rivers, including the Hopkins, Latrobe, Avon and Snowy Rivers.

Compartments that were noted to have a greater amount of activated Coastal Acid Sulphate Soils (CASS) due to STM and flood events within their extents were Torquay, Port Phillip Bay West and the majority of the east coast compartments.

Table 22. Full Study Area Sediment Compartment breakup showing total area coverage, SLR, STM, Flood and CASS in 2040 and 2100

Compartment		Quantity		Sea Level Rise		Storm Surge - 1% AEP		Flooding - 1% AEP		Coastal Acid Sulphate Soils	
		Total	Land	20cm 2040	82cm 2100	20cm SLR 2040	82cm SLR 2100	20cm SLR 2040	82cm SLR 2100	20cm SLR 2040	82cm SLR 2100
1. Discovery Bay											
	Ha	33792.50	26960.25	699.75	880.25	827.75	1124.75	1429.00	1429.00	373.25	580.25
				2.60%	3.26%	3.07%	4.17%	5.30%	5.30%	1.38%	2.15%
2. Portland Bay											
	Ha	33482.25	23551.50	878.75	1940.75	1716.50	2881.25	2286.75	1812.50	2112.75	2594.25
				3.73%	8.24%	7.29%	12.23%	9.71%	7.70%	8.97%	11.02%
3. Warrnambool											
	Ha	27133.25	22226.75	935.25	1848.25	1774.75	2368.00	5170.50	4336.75	2097.50	2160.50
				4.21%	8.32%	7.98%	10.65%	23.26%	19.51%	9.44%	9.72%
4. Port Campbell											
	Ha	22981.25	18815.75	1010.50	2163.00	1917.75	2846.75	4419.25	3335.25	3851.25	3901.25
				5.37%	11.50%	10.19%	15.13%	23.49%	17.73%	20.47%	20.73%
5. Great Ocean Road											
	Ha	11547.00	6754.75	630.50	787.25	808.00	968.75	533.00	440.50	339.50	347.00
				9.33%	11.65%	11.96%	14.34%	7.89%	6.52%	5.03%	5.14%
6. Torquay											
	Ha	27340.50	22805.25	4653.75	6995.75	7167.75	8337.75	5407.50	3202.25	7641.75	7707.00
				20.41%	30.68%	31.43%	36.56%	23.71%	14.04%	33.51%	33.79%
7. Port Phillip Bay Mouth											
	Ha	139.00	11.00	8.50	7.50	8.50	7.75	0.00	0.25	0.00	0.00
				77.27%	68.18%	77.27%	70.45%	0.00%	2.27%	0.00%	0.00%
8. Port Phillip Bay West											
	Ha	91012.25	40724.00	3818.00	5763.25	6190.25	9020.75	6256.50	5692.50	7431.25	9245.75
				9.38%	14.15%	15.20%	22.15%	15.36%	13.98%	18.25%	22.70%
9. Port Phillip Bay East											
	Ha	65353.50	40612.25	1108.00	1927.75	2579.50	6561.50	2484.50	2393.25	2894.75	6443.25
				2.73%	4.75%	6.35%	16.16%	6.12%	5.89%	7.13%	15.87%
10. Nepean Peninsula											
	Ha	3194.75	1161.75	239.75	247.75	273.50	275.75	0.00	0.00	0.00	0.00
				20.64%	21.33%	23.54%	23.74%	0.00%	0.00%	0.00%	0.00%
11. Cape Schanck Flinders											
	Ha	1887.00	1042.75	102.00	111.25	136.00	129.00	0.00	0.00	0.00	0.00
				9.78%	10.67%	13.04%	12.37%	0.00%	0.00%	0.00%	0.00%
12. Western Port											
	Ha	118893.00	66107.25	4831.25	8296.00	16661.25	22980.25	56.00	49.25	8282.00	9637.25
				7.31%	12.55%	25.20%	34.76%	0.08%	0.07%	12.53%	14.58%

Compartment		Quantity		Sea Level Rise		Storm Surge - 1% AEP		Flooding - 1% AEP		Coastal Acid Sulphate Soils	
		Total	Land	20cm 2040	82cm 2100	20cm SLR 2040	82cm SLR 2100	20cm SLR 2040	82cm SLR 2100	20cm SLR 2040	82cm SLR 2100
13. Phillip Island South											
	Ha	3233.00	1728.00	341.00	338.75	370.75	365.75	0.00	0.00	0.00	0.00
				19.73%	19.60%	21.46%	21.17%	0.00%	0.00%	0.00%	0.00%
14. Cape Woolamai Cape Paterson											
	Ha	7723.25	5016.00	381.00	803.75	885.00	1106.75	825.25	483.25	729.75	798.00
				7.60%	16.02%	17.64%	22.06%	16.45%	9.63%	14.55%	15.91%
15. Venus Bay											
	Ha	25429.50	20786.75	4270.75	5485.75	5818.00	6895.00	5388.75	4362.00	5796.00	6213.50
				20.55%	26.39%	27.99%	33.17%	25.92%	20.98%	27.88%	29.89%
16. Waratah Bay											
	Ha	18807.25	12697.50	2209.00	2826.50	2883.00	3426.00	685.75	510.00	1679.75	1904.25
				17.40%	22.26%	22.71%	26.98%	5.40%	4.02%	13.23%	15.00%
17. Wilsons Promontory Southwest											
	Ha	3332.00	1591.75	170.50	230.25	279.25	301.00	0.00	0.00	92.50	107.75
				10.71%	14.47%	17.54%	18.91%	0.00%	0.00%	5.81%	6.77%
18. Wilsons Promontory East											
	Ha	16381.25	6368.00	424.00	803.75	843.00	1191.75	0.00	0.00	472.75	762.50
				6.66%	12.62%	13.24%	18.71%	0.00%	0.00%	7.42%	11.97%
19. Corner Inlet											
	Ha	120980.50	63762.50	17760.50	25521.75	27214.00	31489.25	4583.50	2684.25	23160.75	25416.25
				27.85%	40.03%	42.68%	49.39%	7.19%	4.21%	36.32%	39.86%
20. Gippsland Lakes											
	Ha	199732.00	176354.25	26687.75	42265.25	51247.25	59434.00	75959.75	62693.75	91630.25	93550.50
				15.13%	23.97%	29.06%	33.70%	43.07%	35.55%	51.96%	53.05%
21. Snowy River											
	Ha	45278.75	41931.00	5691.75	7537.75	8782.25	10470.75	11980.50	10254.00	16577.00	16877.00
				13.57%	17.98%	20.94%	24.97%	28.57%	24.45%	39.53%	40.25%
22. Cann River											
	Ha	22253.50	16621.50	1220.75	1771.50	1902.25	3664.00	2901.00	2561.75	3998.00	4801.25
				7.34%	10.66%	11.44%	22.04%	17.45%	15.41%	24.05%	28.89%
23. Mallacoota Inlet											
	Ha	29970.25	23185.75	3924.25	4754.50	5077.75	5741.50	401.50	371.50	5167.50	5736.50
				16.93%	20.51%	21.90%	24.76%	1.73%	1.60%	22.29%	24.74%
Full Study Area											
	Ha	929877.50	640816.25	81997.25	123308.25	145364.00	181588.00	130769.00	106612.00	184328.25	198784.00
				12.80%	19.24%	22.68%	28.34%	20.41%	16.64%	28.76%	31.02%

9.4 DELWP Coastal Priority Assets

DELWP Priority Assets across the study area were depicted as either a line or polygon feature. No assets were identified as a point. The majority of features were only found at a local level and were hence constrained to a single sediment compartment. Some assets, like the Great Ocean Road or National Parks, were found to extend over two or more compartments. Table 23 presents examples of the analysis findings for Priority Assets within the Great Ocean Road sediment compartment. Results for the combined high/very high erosion ratings, SLR and STM for 2040 and 2100 and significance are presented.

Taking the Great Ocean Road line feature as an example, there was 66.37 km of road within the study area found within the Great Ocean Road compartment. Of this about 6km or 9% was affected by high or very high coastal erosion. By 2040 it was estimated that 11.5 km would be impacted by SLR of up to 20cm, which by 2100 at 87cm could affect nearly 25% of the length of the Great Ocean Road.

Table 23. Priority Assets within the Great Ocean Road Compartment showing total area coverage, High and Very High Coastal Erosion Vulnerability ratings and SLR and STM in 2040 and 2100

Priority Asset Name	Quantity	Unit	High & Very High	Sea Level Rise		Storm Surge - 1% AEP		Significance Ranking
				20cm	82cm	20cm SLR	82cm SLR	
	Total - Land			2040	2100	2040	2100	
GREAT OCEAN ROAD - HERITAGE	193.04	Ha	16.77	28.10	39.94	40.10	51.42	2
			17.23%	29.00%	41.23%	41.45%	53.04%	
GREAT OCEAN ROAD - ROAD	66.37	Km	5.97	11.54	16.41	16.41	21.08	2
			8.99%	17.39%	24.72%	24.72%	31.76%	
GREAT OCEAN ROAD LANDSCAPE - NATIONAL	110.44	Km	13.30	93.22	94.90	98.11	95.87	2
			12.04%	84.41%	85.93%	88.84%	86.81%	
GREAT OCEAN ROAD LANDSCAPE - STATE	127.23	Km	15.09	107.45	109.13	113.06	110.20	3
			11.86%	84.45%	85.77%	88.86%	86.61%	
APOLLO BAY BOAT RAMP A	0.03	Km	0.00	0.03	0.03	0.03	0.03	4
			0.00%	100.00%	100.00%	100.00%	100.00%	
APOLLO BAY BOAT RAMP B	0.05	Km	0.00	0.02	0.02	0.02	0.02	4
			0.00%	50.00%	50.00%	50.00%	50.00%	
APOLLO BAY WHARF	0.33	Km	0.00	0.13	0.13	0.13	0.13	4
			0.00%	40.00%	40.00%	40.00%	40.00%	
APOLLO BAY WHARF B	0.06	Km	0.00	0.06	0.06	0.06	0.06	4
			0.00%	100.00%	100.00%	100.00%	100.00%	
GREAT OTWAY NATIONAL PARK	2,482.54	Ha	29.40	256.34	288.41	299.10	313.57	2
			1.18%	10.33%	11.62%	12.05%	12.63%	

A similar narrative for a more natural compartment, such as the Corner Inlet Compartment, is presented in Table 24. This compartment contained a large area of National Park and natural landscapes. Taking the Wilsons Promontory National Park as an example, within the study area there was over 4,500 hectares of this asset. Of this, about 2% was affected by high or very high coastal erosion, which was as expected since the natural land cover is anticipated to assist in providing resilience for this asset in relation to coastal erosion. However, 880 hectares by 2040 is estimated to be impacted by storm surge events, which by 2100 would increase to nearly 1,000 hectares.

Table 24. Priority Assets within the Corner Inlet Compartment showing total area coverage, High and Very High Coastal Erosion Vulnerability ratings and SLR and STM in 2040 and 2100

Priority Asset Name	Quantity Land	Unit	High & Very High	Sea Level Rise 20cm 2040	Sea Level Rise 82cm 2100	Storm Surge - 1% AEP 20cm SLR 2040	Storm Surge - 1% AEP 82cm SLR 2100	Significance Ranking
19. Corner Inlet								
WILSONS PROMONTORY LANDSCAPE - STATE	60.16	Km	22.72 37.76%	48.90 81.27%	48.58 80.74%	51.81 86.11%	49.50 82.27%	3
WILSONS PROMONTORY NATIONAL PARK	4,546.94	Ha	95.22 2.09%	438.41 9.64%	845.15 18.59%	880.92 19.37%	997.89 21.95%	2
WILSONS PROMONTORY MARINE PARK	1.08	Ha	1.08 100.00%	0.72 66.67%	1.08 100.00%	0.90 83.33%	1.08 100.00%	2
GIPPSLAND LAKES LANDSCAPE - STATE	8.51	Km	8.51 100.00%	5.70 66.95%	5.48 64.44%	5.70 66.95%	5.48 64.44%	2
CORNER INLET - RAMSAR	22,213.96	Ha	3,674.65 16.54%	13,484.30 60.70%	16,398.78 73.82%	17,156.24 77.23%	18,408.68 82.87%	1
CORNER INLET LANDSCAPE - REGION	750.17	Km	269.69 35.95%	467.80 62.36%	453.07 60.40%	470.38 62.70%	451.46 60.18%	4
CORNER INLET MARINE & COASTAL PARK	2,902.42	Ha	277.25 9.55%	2,403.76 82.82%	2,590.48 89.25%	2,614.34 90.07%	2,604.01 89.72%	2
NOORAMUNGA MARINE & COASTAL PARK	18,171.72	Ha	3,167.90 17.43%	9,826.85 54.08%	12,336.98 67.89%	12,990.61 71.49%	14,171.33 77.99%	2
CORNER INLET MARINE NATIONAL PARK	176.92	Ha	65.55 37.05%	159.06 89.91%	160.94 90.97%	164.70 93.09%	161.65 91.37%	2

Application to Priority Assets

Priority Assets, as recognised by DELWP are presented in Section 8.6. These assets can cover a considerable length or area, or can be constrained to a small locality. The top panel in Figure 27 provides a broad spatial representation of these Priority Assets along the coastline, while the bottom panel identifies the level of significance assigned to each priority asset. This lower panel identifies that there are a number of internationally significant sites in and around Port Phillip Bay and Westernport, primarily the RAMSAR wetlands and Biosites at these locations. Assets of National significance are distributed across the coastline and can include National Parks, tourism destinations and significant landscapes.

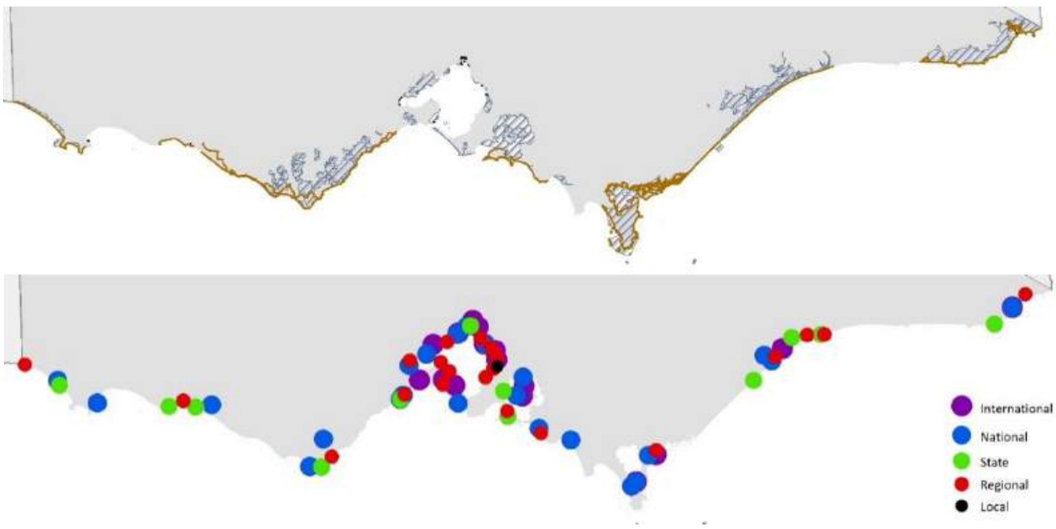

Figure 27. Distribution of DELWP Priority Assets across the Victorian coastline (top panel) and the level of significance based on an international to local scale.

Figure 28 presents Priority Assets for a section of the Gippsland Lakes Region. The highest rating has been assigned to RAMSAR wetlands with parks and reserves assigned a national rating. Boating facilities have been assigned a rating of state or regional scale importance.

This example shows how level of significance can be a useful way to differentiate asset levels of importance.

It is also noted however, that at the regional level the assets identified may have equal importance to residents or visitors as compared with parks or landscapes.

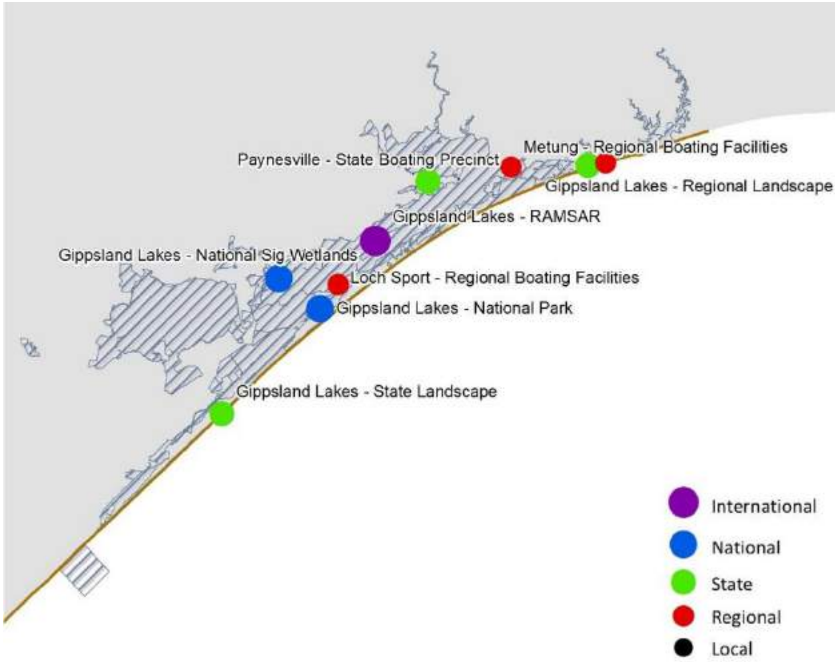

Figure 28. **Cross section of the Gippsland Lakes Region detailing DELWP priority assets and levels of significance**

Figure 29 provides a second example of Priority Assets, in this case for the Colac-Otway and Surf Coast areas. Key Priority Assets for this section of the coast included the Great Ocean Road, regional boating facilities at Apollo Bay and Torquay, and National Parks. Some assets, like the Great Ocean Road, had several different values, such as tourism and heritage.

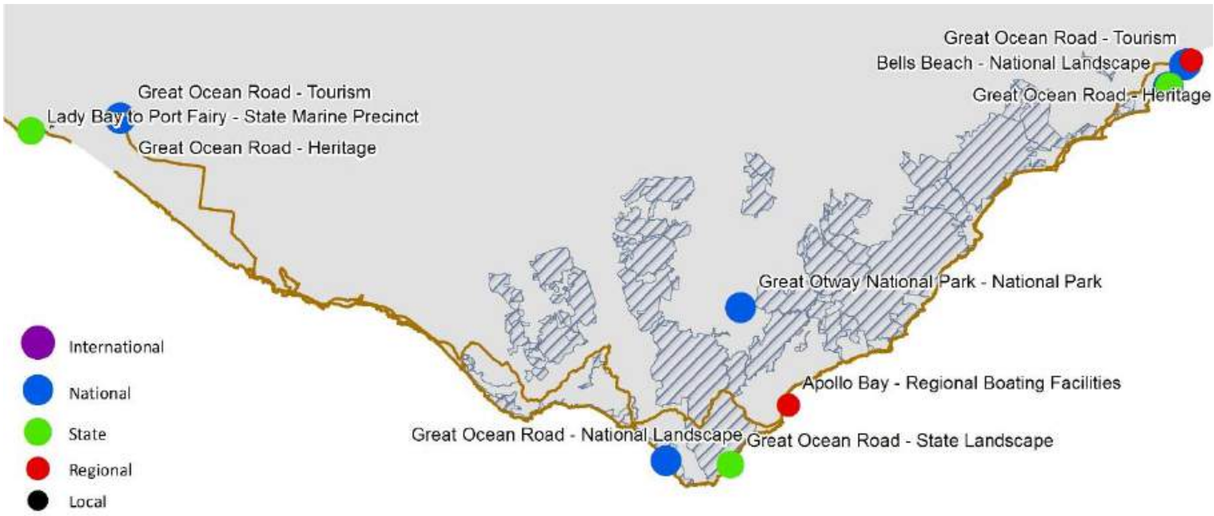

Figure 29. **DELWP Priority Assets along the Colac-Otway and Surf Coast Regions of western Victoria with assigned significance levels.**

Figure 30 identifies the relationship between these same sites and the coastal erosion vulnerability rating. The top panel presents assets that were found to have none of their total area affected by High or Very High ratings. The bottom panel presents assets which were identified to have at least 10% of their total area affected. All assets are again identified in terms of their significance as assigned in the DELWP studies.

Assets that indicated no area affected still could have moderate or lower ratings.

Priority Assets such as the Great Ocean Road were found to have higher erosion risks than that of many other assets, such as boating facilities.

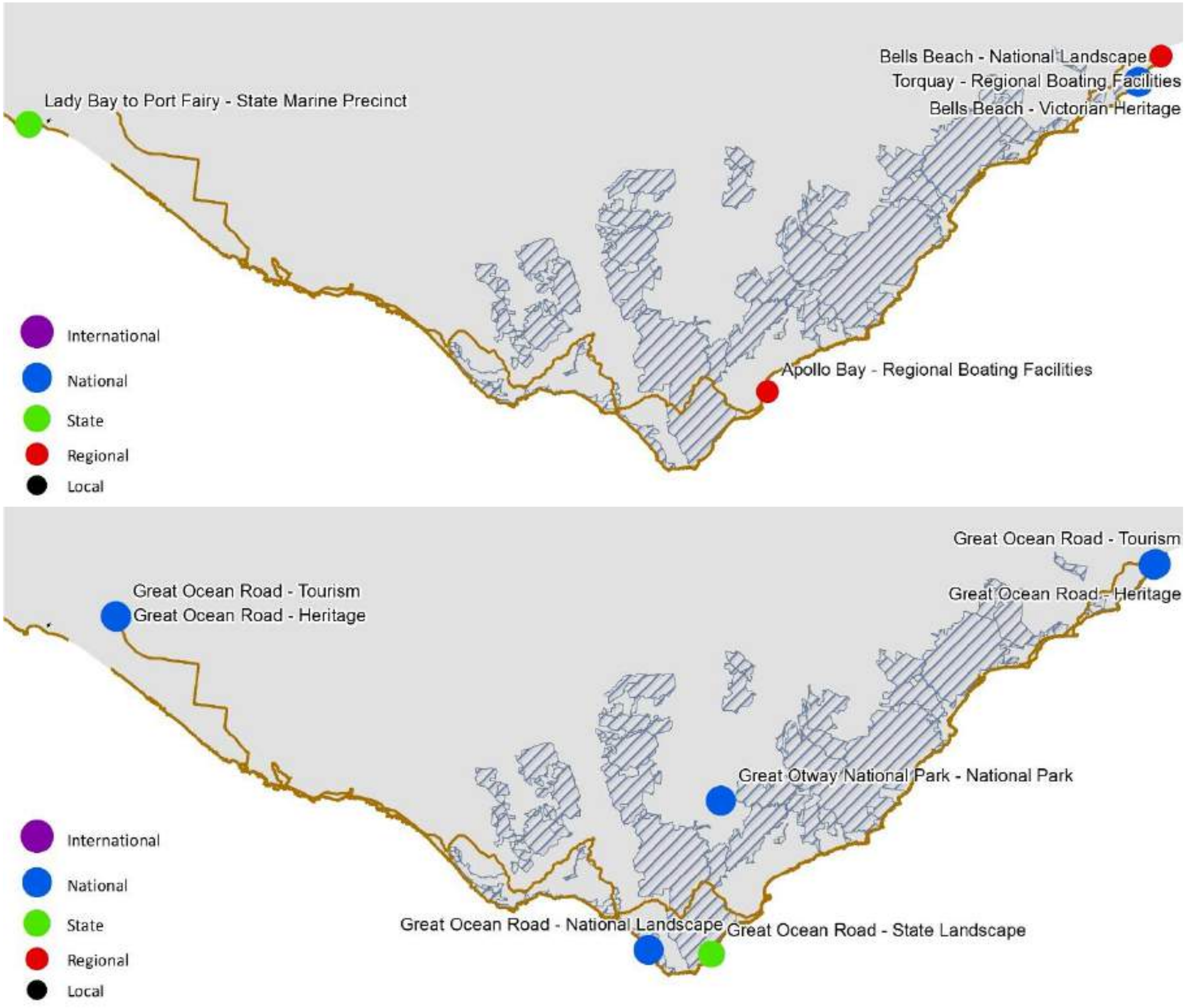

Figure 30. DELWP Priority Assets along the Colac-Otway and Surf Coast Regions of western Victoria with assigned Coastal Erosion Vulnerability ratings. The top panel indicates assets that have none of the area affected by High or Very High ratings, and the bottom panel indicates beaches that have at least 10% of their area affected.

9.5 Application to Other High Value Assets

Other high value coastal assets identified by stakeholders that provide a significant level of service were:

- Residential Property
- Commercial property
- Surf lifesaving clubs & linked beaches

- Key beaches
- Camping grounds
- Caravan Parks
- State/Regional Boating Facilities
- Major piers and jetties
- Critical infrastructure – power, gas, water treatment
- Critical services – communication, police, hospital, fire

These assets could be represented spatially as either point, line or polygon features, but the majority presented as a line or polygon features.

An example of an output report for the Residential Property high value asset is shown in Table 25. This table presents the results for the combined high/very high erosion ratings, SLR and STM for 2040 and 2100 for each secondary level coastal sediment compartment.

Using the Port Phillip Bay East compartment as an example, the results show over 14,000 hectares were considered as residential planning zone with over 15% of this area influenced by high and very high coastal erosion, but relatively small amount impacted by inundation factors. Comparing this to a less urbanised compartment, like Port Campbell, it was noted that percentage breakdowns are similar amount, but the underlying hectares are considerably lower for the less urbanised compartments.

Table 25. Residential property along the Victorian coastline showing total area coverage, High and Very High Coastal Erosion Vulnerability ratings and SLR and STM in 2040 and 2100

Compartment	Unit	Quantity Land	H/VH	2040 SLR	2100 SLR	2040 STM	2100 STM
Discovery Bay							
Quantity	Ha	791.97	11.27	2.07	6.01	3.38	22.72
Percentage			1.42%	0.26%	0.76%	0.43%	2.87%
Portland Bay							
Quantity	Ha	2808.1	375.42	48.7	124.61	97.4	222.8
Percentage			13.37%	1.73%	4.43%	3.46%	7.91%
Warrnambool							
Quantity	Ha	3090.54	108.38	74.39	165.53	153.36	244.32
Percentage			3.51%	2.41%	5.35%	4.96%	7.90%
Port Campbell							
Quantity	Ha	1191.74	79.71	5.72	36.17	26.57	100.39
Percentage			6.69%	0.48%	3.03%	2.23%	8.42%
Great Ocean Road							
Quantity	Ha	1352.21	127.44	7.3	24.92	22.96	53.58
Percentage			9.42%	0.54%	1.84%	1.70%	3.96%
Torquay							
Quantity	Ha	4364.39	370.36	146.97	374.1	419.41	672.66
Percentage			8.49%	3.37%	8.57%	9.61%	15.41%
Port Phillip Bay West							
Quantity	Ha	7009.7	286.12	177.89	348.2	390.34	805.54
Percentage			4.08%	2.54%	4.97%	5.57%	11.49%
Port Phillip Bay East							
Quantity	Ha	14404.45	2221.52	113.83	293.8	472.58	1880.05
Percentage			15.42%	0.79%	2.04%	3.28%	13.05%
Nepean Peninsula							
Quantity	Ha	29.39	0	0	0	0	0
Percentage			0.00%	0.00%	0.00%	0.00%	0.00%
Cape Schank Flinders							
Quantity	Ha	522.99	0	17.91	22.23	30.43	29.79
Percentage			0.00%	3.42%	4.25%	5.81%	5.69%
Western Port							
Quantity	Ha	11865.76	422.62	241.47	599.27	1908.46	3141.67

Compartment	Unit	Quantity Land	H/VH	2040 SLR	2100 SLR	2040 STM	2100 STM
Percentage			3.56%	2.03%	5.05%	16.08%	26.48%
Phillip Island South							
Quantity	Ha	132.81	0.33	1.65	2.3	3.46	4.44
Percentage			0.25%	1.24%	1.73%	2.60%	3.35%
Cape Woolamai Cape Paterson							
Quantity	Ha	537.95	47.29	3.65	14.08	17.91	25.38
Percentage			8.79%	0.68%	2.62%	3.33%	4.72%
Venus Bay							
Quantity	Ha	1552.1	295.21	114.97	195.85	220.73	370.89
Percentage			19.02%	7.40%	12.61%	14.21%	23.88%
Waratah Bay							
Quantity	Ha	445.45	69.49	28.17	47.99	45.03	118.78
Percentage			15.60%	6.32%	10.77%	10.11%	26.66%
Corner Inlet							
Quantity	Ha	3146.02	139.16	354.34	801.46	894.79	1140.9
Percentage			4.42%	11.26%	25.48%	28.44%	36.26%
Gippsland Lakes							
Quantity	Ha	15008.24	1453.5	1128.29	2426.43	3511.63	4667.55
Percentage			9.69%	7.52%	16.17%	23.40%	31.10%
Snowy River							
Quantity	Ha	1678.46	25.44	22.04	40.14	50.53	102.85
Percentage			1.52%	1.31%	2.39%	3.01%	6.13%
Cann River							
Quantity	Ha	37.57	1.34	0	1.74	2.01	9.63
Percentage			3.56%	0.00%	4.63%	5.34%	25.62%
Mallacoota Inlet							
Quantity	Ha	389.99	9.05	24.08	29.03	30.05	35.17
Percentage			2.32%	6.17%	7.44%	7.71%	9.02%
Full Area							
Quantity	Ha	70359.91	6118.07	2460.81	5440.4	8068.45	13409.72
Percentage			8.70%	3.50%	7.73%	11.46%	19.05%

Table 26 presents the same analysis for two water treatment plants, Werribee and Wonthaggi, and shows the level to which both treatment plants were estimated to be potentially impacted by coastal erosion and inundation. The Western Werribee treatment plant was noted to have over 35% of its total area impacted by coastal erosion, over 2.5% by SLR by 2040 and nearly 13.5% by STM by 2040. The Eastern Treatment Plant was identified to have only 20% of its total area was impacted by coastal erosion, none of its area by SLR by 2040 and 1.2% by STM by 2040.

Table 26. Key water treatment plants along the Victorian coastline showing total area coverage, High and Very High Coastal Erosion Vulnerability ratings and SLR and STM in 2040 and 2100

Compartment	Unit	Quantity Land	H/VH	2040 SLR	2100 SLR	2040 STM	2100 STM
Port Phillip Bay West							
WESTERN TREATMENT PLANT	Ha	2037.8					
Quantity			724.2	57.0	205.4	273.3	860.5
Percentage			35.54%	2.80%	10.08%	13.41%	42.23%
Port Phillip Bay East							
EASTERN TREATMENT PLANT	Ha	771.3					
Quantity			157.4	0	5.8	8.9	97.2
Percentage			20.41%	0.00%	0.76%	1.15%	12.60%
Cape Woolamai Cape Paterson							
WONTHAGGI DESALINATION PLANT	Ha	264.4					
Quantity			8.6	0	9.5	10.4	35.8
Percentage			3.26%	0.00%	3.60%	3.95%	13.55%

PART 5 – RISK ASSESSMENT APPROACH – CASE STUDY

10. Application of Risk to Assets

10.1 Proposed Risk Framework for Coastal Assessment

This section outlines a possible application of the outputs of this project in a standard risk assessment framework.

The risk framework combines the likelihood of an area being impacted (which would be defined as vulnerability in terms of this coastal study), and the consequence of the asset being impacted. Consequence in this example was defined in terms of the assessed importance or significance of the asset.

The case study example presented relates to beaches.

This risk assessment framework is presented in Figure 31. The framework accommodates likelihood to coastal erosion and inundation impacts, and hence the dynamic natural forces that act on coastal interfaces (sea level, tide and wave energy/direction, ground and surface water flows), and focuses on consequence in terms of assets assessed to provide the greatest benefit to the community. The Adaptive Capacity and resultant Vulnerability based on implementation of mitigation controls are additional aspects of this Risk Framework and relate to actions undertaken outside of this coastal assessment project. Hence, they are referenced with the qualifier of '(2)'.

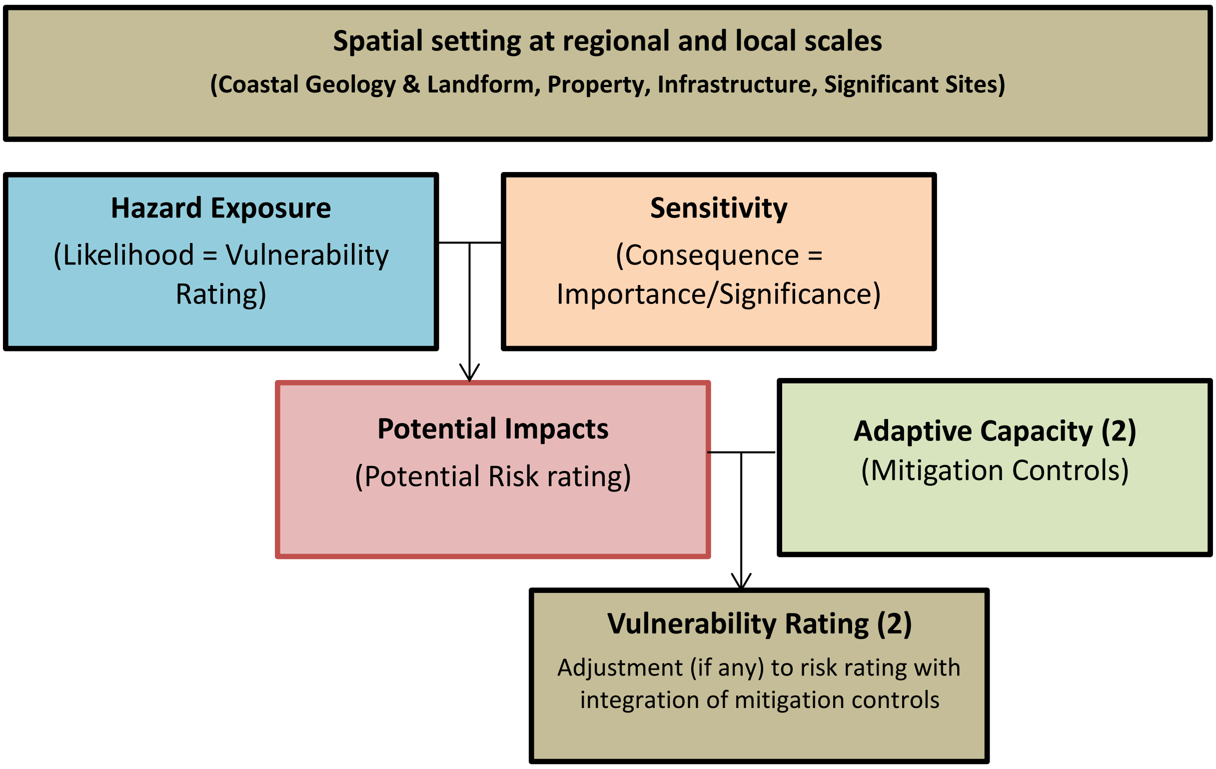

Figure 31. Schematic diagram illustrating integration of spatial asset data with criteria and attributes used for coastal climate change risk and vulnerability assessments that inform coastal monitoring requirements.

(Hazard Exposure: refers to how likely assets in the coastal zone are or will be exposed to hazards, which may or may not be exacerbated by climate change phenomena; Sensitivity: reflects the relative consequences expected (adversely or beneficially) by such hazards; Adaptive capacity: describes the level of controls and changes need and what was possible to ameliorate risks and their impacts; and Vulnerability: expresses the adjusted risk and impact to people and assets in the coastal zone from hazards after integration of mitigation controls and/or willingness to adapt).

10.2 Case Study of Victorian Beaches

The concept of Risk is the potential of losing or gaining something of value based on particular actions or inactions. A risk assessment, or analysis, is the process in which these potential risks are evaluated and the projected consequences are defined based on this action or inaction. In relation to the coastal areas of Victoria, and in this case study example applied to beaches, the risk analysis helps define the projected outcomes to particular beaches based on coastal erosion and inundation factors.

Using a measure relating to the proximity of a beach to the population they likely service, is one approach to assessing the likely consequence or significance of a particular beach.

Figure 32 provides an example of a risk assessment matrix. This matrix provides a means of assessing a probability or likelihood score against a set of consequences to determine a likely risk category. In this example a very high likelihood score with an extreme consequence would equate to the highest (extreme) risk category for an asset, whereas a very low probability score with an insignificant consequence would pose a low risk.

This case study applies this approach to the Victorian beaches, with the probability scores based on Coastal Erosion Vulnerability ratings and the Inundation Factors. Consequences have been assessed based on a significance score based on proximity of a beach to the population they likely service.

Further details on the proximity significance rating assigned to beaches, and its applications in reviewing beaches likely to be impacted by earlier coastal erosion or inundation factors, is presented in Section 10.3.

Hence for this case study, coastal erosion vulnerability ratings ranging from 1 to 5, where 5 was Very High, were combined with consequence ratings based on proximity significance where the lowest rating of insignificant relates to a proximity of 1 and extreme relates to a proximity of 5. The resultant potential risk rating was a rating that adopts the terms Low to Extreme, where multiplied values were assigned back to a 4 category rating system based on the classes presented.

	Consequences				
Score	**Insignificant**	**Minor**	**Moderate**	**Major**	**Extreme**
Very High	Medium	Medium	High	Extreme	Extreme
High	Low	Medium	High	Extreme	Extreme
Moderate	Low	Medium	Medium	High	Extreme
Low	Low	Medium	Medium	High	High
Very Low	Low	Low	Medium	Medium	Medium

Figure 32. Risk assessment matrix example.

Figure 33 presents the Coastal Erosion Vulnerability ratings for the north-eastern coast of Port Phillip Bay. This figure shows how the Chelsea to Frankston Foreshores have the higher r Vulnerability ratings than beaches to the north within this area.

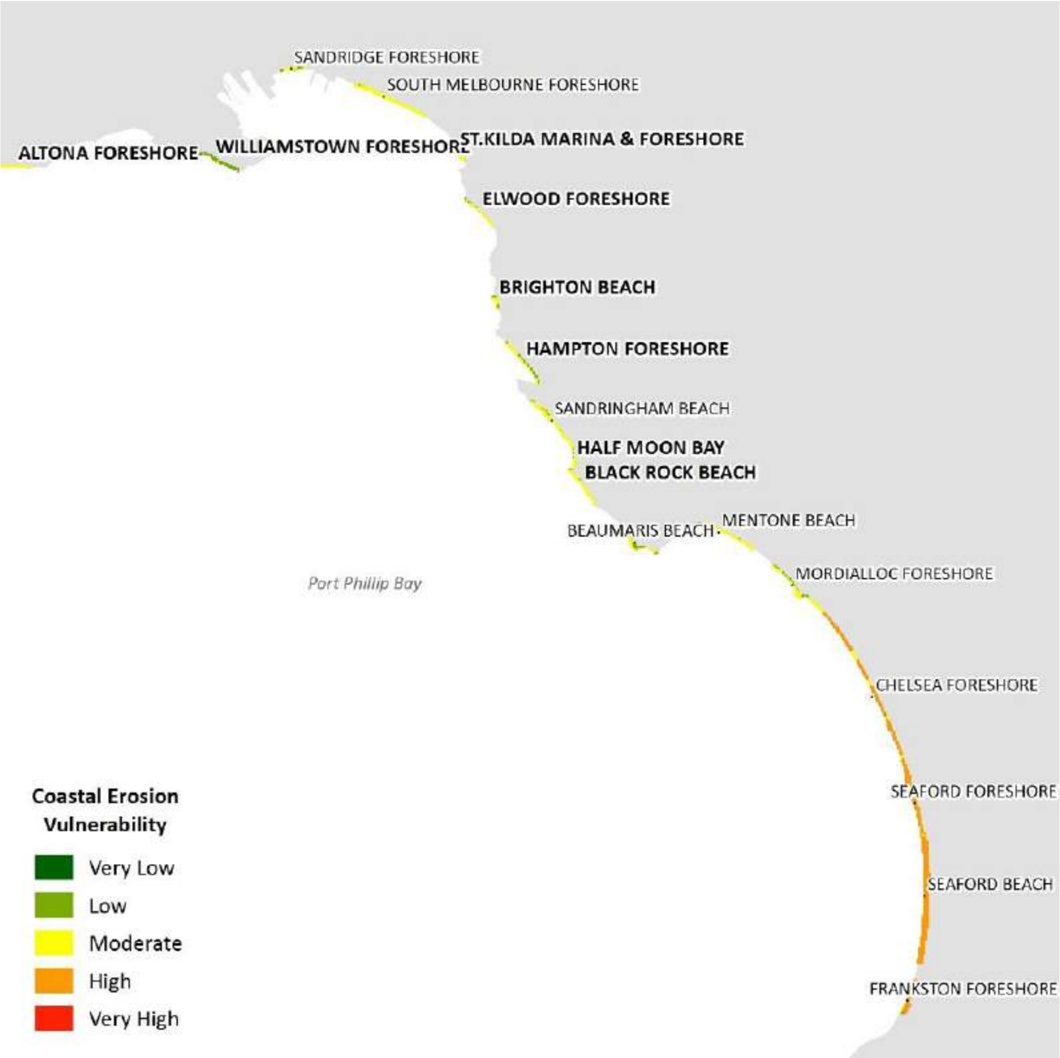

Figure 33. Coastal Erosion Vulnerability ratings for the north eastern coast of Port Phillip Bay.

Figure 34 presents the potential risk rating based on combination the coastal erosion vulnerability (or Hazard Exposure) scores with the proximity ratings. This view shows how some of the beaches that had a high exposure hazard rating, such as Seaford Beach, have an assessed minor Risk Category on the basis of a low serviced population or proximity significance rating.

In contrast, some of the northern beaches in this region, such as Brighton, St. Kilda and South Melbourne Foreshore, were assessed to have a high risk based on their high risk proximity significance rating.

Thus, in this application of risk to erosion and proximity, a high significance beach with only moderate coastal erosion can be categorised as a high risk, whereas a lower proximity significance beach with a high erosion score may be categorised as a lower risk due to its lower level of service to population centres.

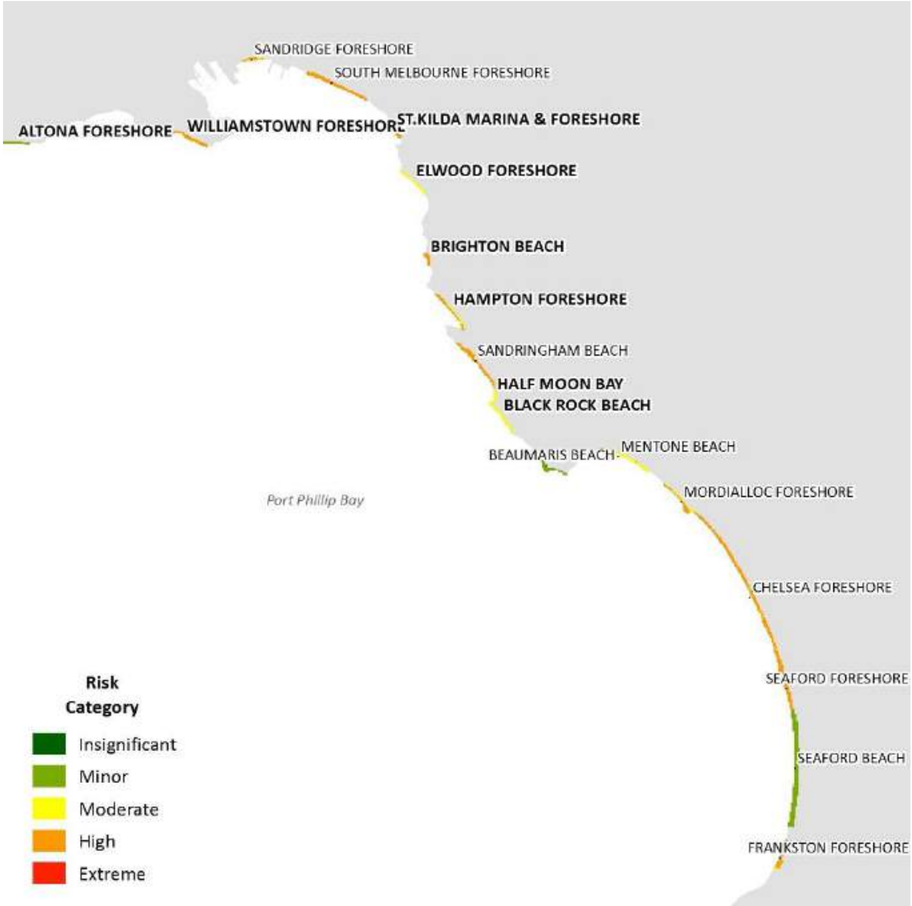

Figure 34. Risk assessment ratings for the north eastern coast of Port Phillip Bay as applied back to coastal erosion and to proximity significance.

This same approach could be applied to Sea Level Rise and other inundation factors. However, since inundation was only recorded as being present or absent for a given 50m by 50m grid cell location for a particular timeframe, the approach adopted in this example was to use % coverage of the beach asset as a measure of Hazard Exposure. Hence, each beach was assigned a hazard score from Very Low (1), which represented a coverage rating from 0%, through to >0% to 25% that was represented as Low (2), 25% to 50% as Moderate (3), 50% to 75% as High (4), and 75% to 100% as Very High (5). This Hazard Exposure score from 1 to 5 score was then multiplied against the proximity scores, to calculate a risk rating for inundation.

Figure 35 presents the result of undertaking this assessment for same study region in Port Philip Bay for the 20cm SLR anticipated for the year 2040. The results show that the majority of the northern beaches in this region were identified as a high risk rating, with Sandringham identified as an extreme risk. Given the uniform increase in SLR, it was clear that the beach proximity significance rating based on the level of service to population centres was the main factor determining the assigned potential risk ratings.

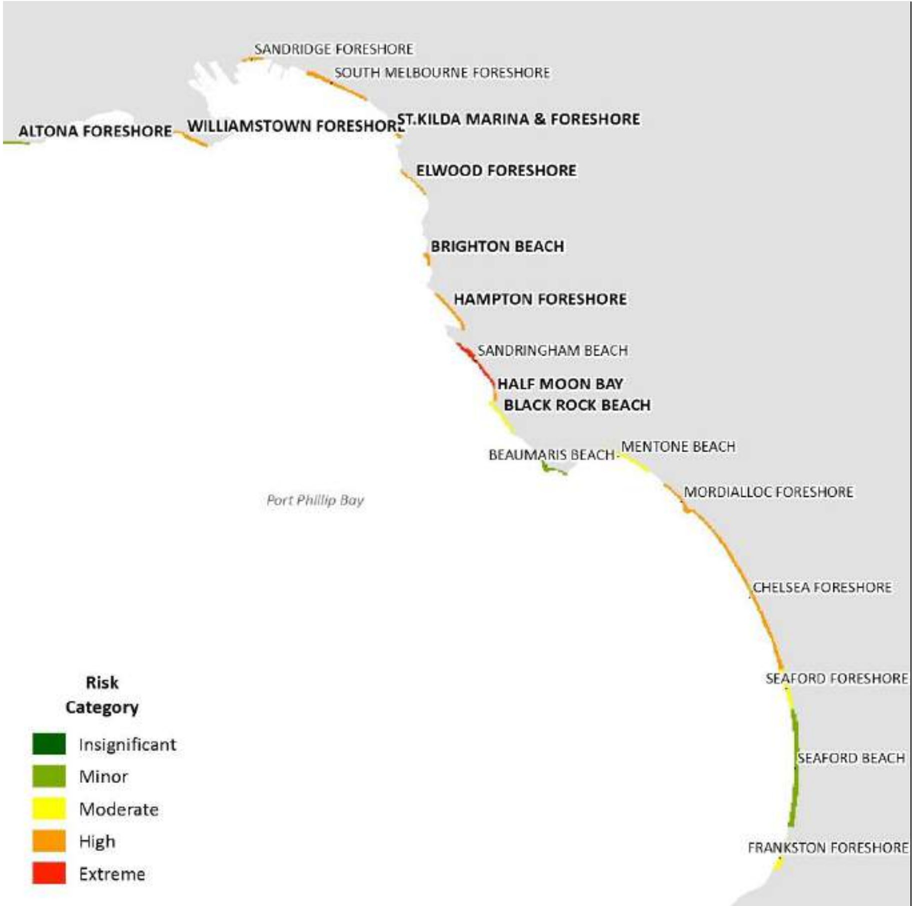

Figure 35. **Risk assessment ratings for the north eastern coast of Port Phillip Bay as applied back to sea level rise in 2040 and to proximity significance.**

This risk assessment approach was applied to other coastal segments along the Victorian coastline. Figure 36 presents the results obtained for the Bells Beach, Jan Juc and Torquay region along the Surf Coast. The left panel of this figure presents the coastal erosion vulnerability rating scores are presented with a breakdown from Very Low to Very High. Most of the area in these three beaches were assessed to have a moderate rating, with some areas showing low scores. The right hand panel shows the assessed potential risk rating based on this coastal hazard exposure rating in combination with the assessed beaches proximity significance. The figure identifies all three beaches to have a high risk rating.

Figure 37 provides a view of the area further south that includes Lorne Beach. The left panel again presents the coastal erosion vulnerability rating scores, and indicates a low to moderate rating for the majority of the beach. The right panel shows the assessed potential risk rating based on this coastal hazard exposure rating in combination with the assessed beaches proximity significance. This view identifies how the southern section of the beach denotes a moderate risk, whereas the central area and portion of the upper beach show high to extreme risks based of erosion.

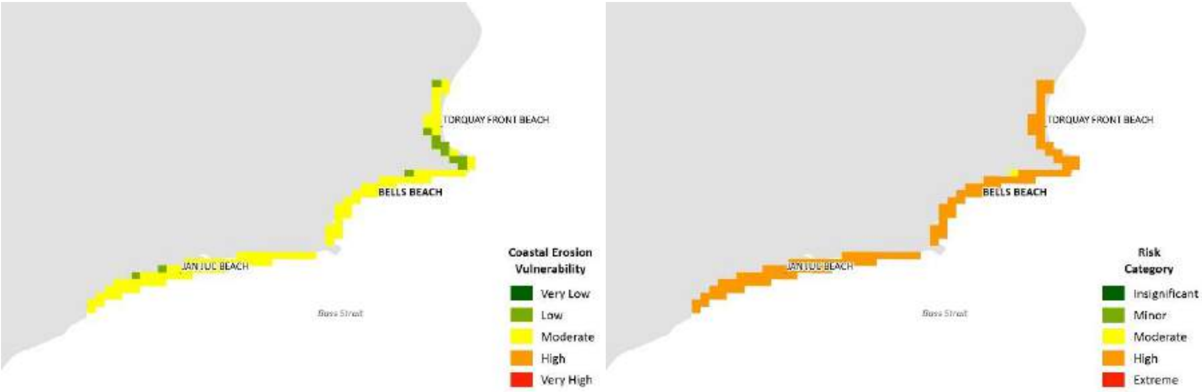

Figure 36. Coastal Erosion Vulnerability ratings for the Bells Beach region of the Surf Coast (left panel) and risk assessment ratings as applied back to coastal erosion and to proximity significance (right panel).

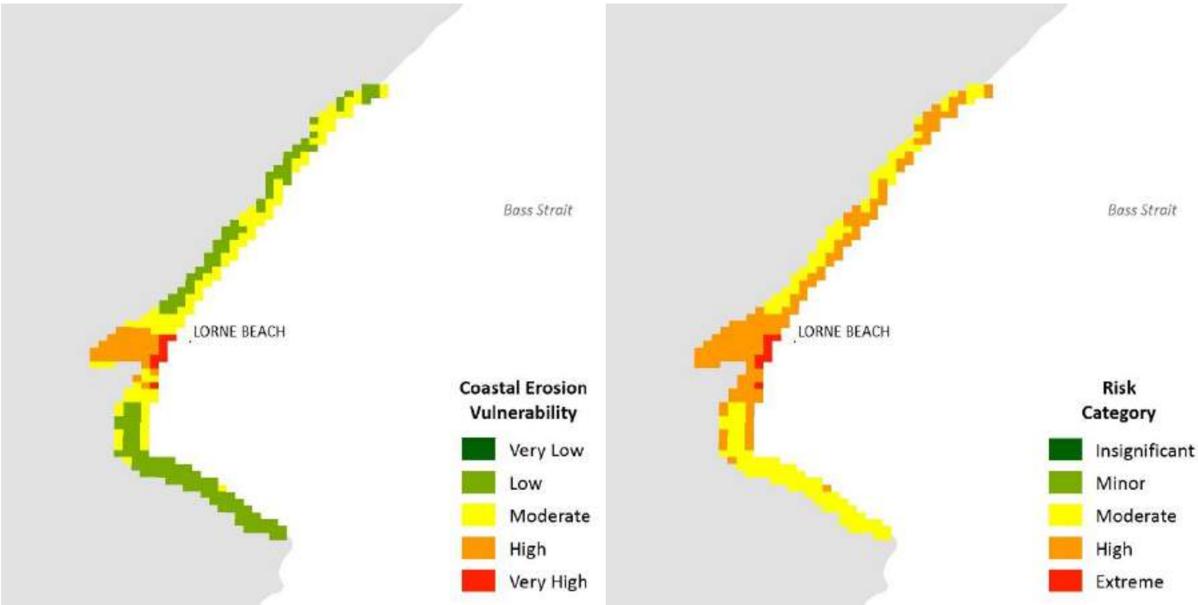

Figure 37. Coastal Erosion Vulnerability ratings for the Lorne foreshore region of the Surf Coast (left panel) and risk assessment ratings as applied back to coastal erosion and to proximity significance (right panel).

The same risk assessment approach was applied to some more remote, or inaccessible beaches into the states east are shown from Inverloch to Wilsons Promontory (Figure 38). In the top panel the Coastal Erosion Vulnerability ratings is for beaches and reserves including Cape Liptrap to Venus Bay and Waratah Bay beaches are presented and show these areas to have a high or very high rating. Tidal River and Squeaky Beach were also identified to have very high ratings.

The result of incorporating proximity significance information is presented in the bottom panel. This view shows that beaches, including Waratah Bay and Tidal River were assigned an extreme potential risk rating due to their proximity to a major town or centre.

This view also provides an example of how some of the remote beaches along the coast could potentially have lower risks based off their significance.

Obviously, the approach used in applying proximity significance is only one example of the many approaches that could be used to assign a significance or importance rating to an asset.

Never the less, this application of a proximity significance measure was viewed to provide a useful example of how a risk analysis assessment rating could provide a valuable insight into prioritisation of planning and management actions in relation to assets along the Victorian coastline.

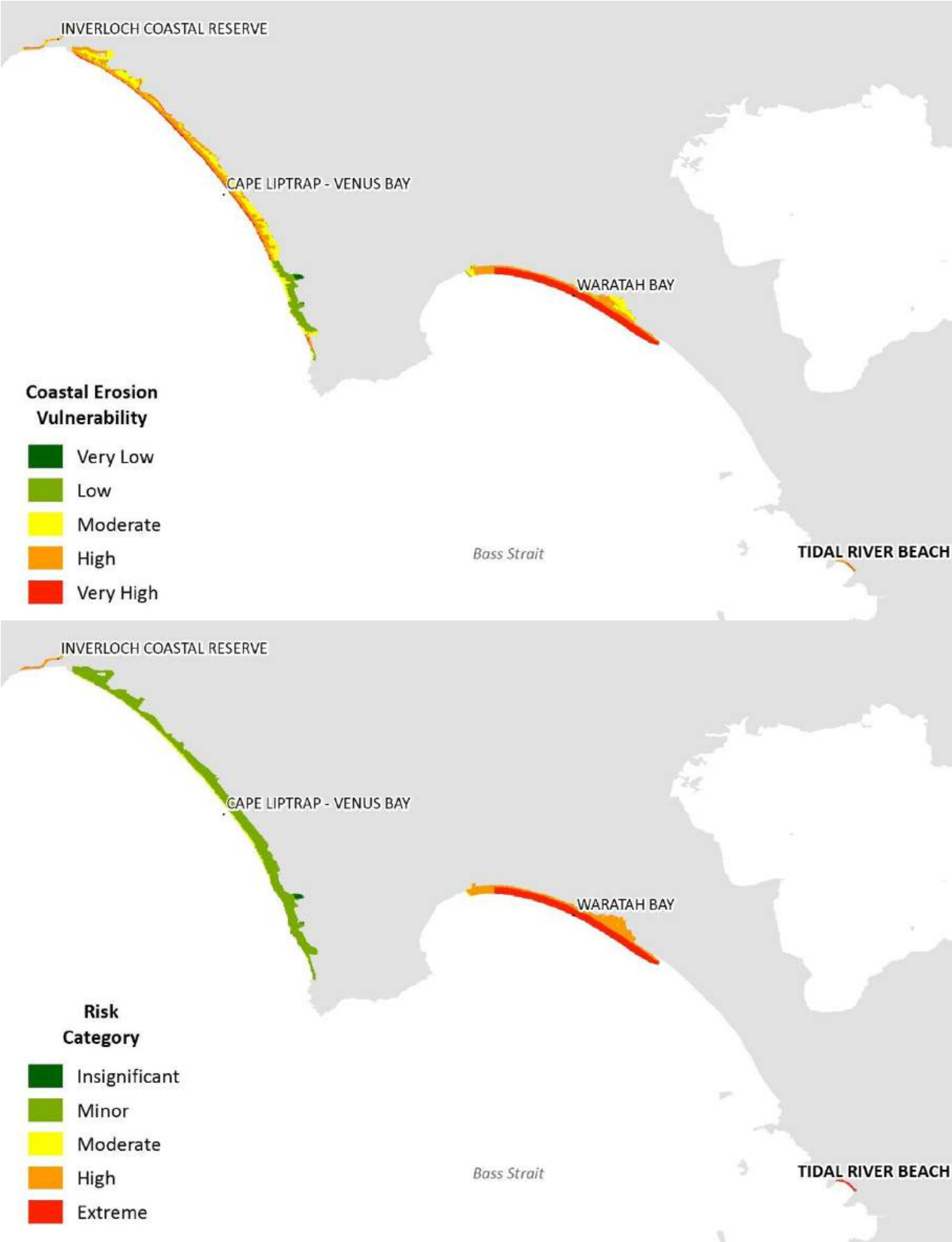

Figure 38. Coastal Erosion Vulnerability ratings for the Inverloch to Wilsons Promontory region (top panel) and risk assessment ratings as applied back to coastal erosion and to proximity significance (bottom panel).

10.3 Application of Study Findings to Victorian Beaches

Beaches on the Victorian coastline were considered a high value asset both due to the recreational and social service they provided as well as the economic input they had at the local, regional and state level. Some beaches were also viewed as significant from an international perspective, such as Bells Beach and the 12 Apostles.

More than 20 significant beaches were identified based on these social or economic values. These beaches have been identified through respective management plans and strategies, as well as tourism portal sites such as Visit Victoria. They comprise:

- St Kilda Marina & Foreshore
- Bells Beach
- Fair Haven
- Raafs Beach
- Smiths Beach
- Cape Woolamai
- Tidal River Beach 7 Squeaky Beach
- Thirteenth Beach
- Eastern Beach
- 90-Mile Beach
- Brighton
- 12 Apostles
- Sorrento
- Altona Foreshore
- Hampton Beach
- The Oaks
- Kilcunda
- Gunnamatta Beach
- Point Leo
- Elwood
- Half-moon Bay
- Black Rock
- Mothers Beach – Mornington Foreshore
- Williamstown Foreshore

Most beaches were found to be associated with one or more local Surf Life Saving Clubs (SLSCs), as shown in the distribution of **Error! Reference source not found.**. This was to be expected as an accessible beach will generally draw visitors and hence may require this service. However, some beaches may, for some reason or another, not have an associated SLSC. Figure 40 shows how the 12 Apostles in the west or Kilcunda in the east do not have associated SLSCs. Most identified beaches and associated SLSC were located within a distance of Port Phillip Bay or along the Surf Coast.

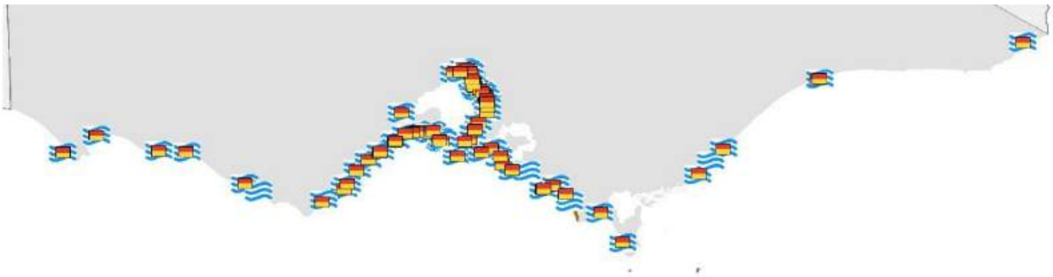

Figure 39. Surf Life Saving Clubs and beaches across the Victorian coastline

Figure 40. Close-up view of the far western coastline, left and Nepean Peninsula/Phillip Island coast, right showing some non-SLSC beaches.

Figure 41 presents a view of the north-east coastline of Port Philip Bay that includes significant beaches such as St. Kilda Foreshore, Altona and Brighton Beach. A number of local beaches that were not considered as significant, are still important at a local level, and are serviced by a SLSC.

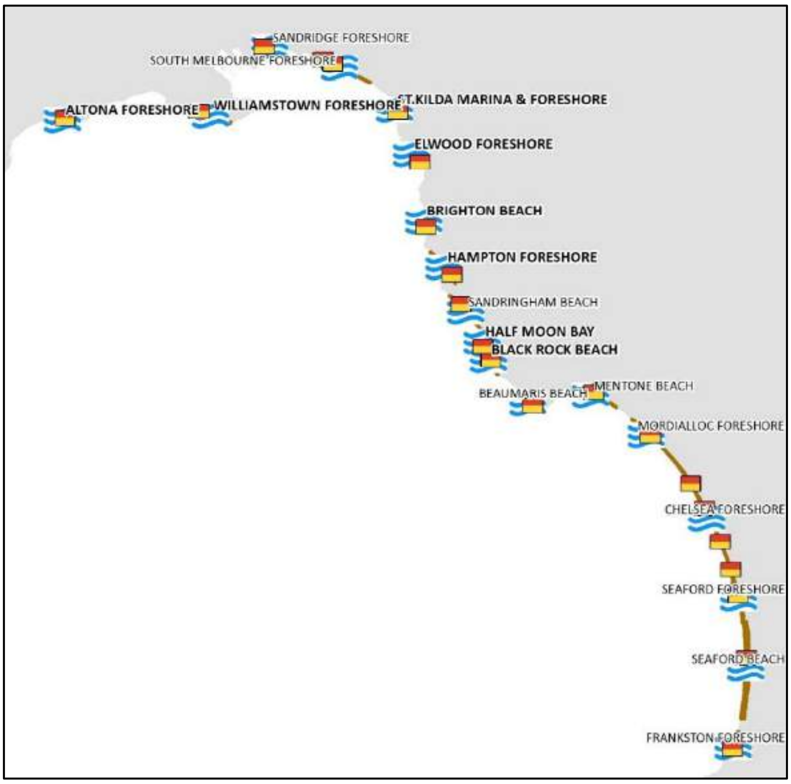

Figure 41. Significant and local beaches and SLSC along the northeast Port Phillip Bay Region. Significant beaches have emphasised label text.

One way of assigning a significance measure to these beaches can be through assessing the proximity of a particular beach to major population hubs. Figure 42 presents this proximity significance for the same selection of beaches along the north-eastern coast of Port Phillip Bay. Using a 1 to 5 scoring system, the distance of these beaches to population hubs based on an incremental kilometre search radius was assessed. Beaches that were assessed to be one kilometre or less from a major location were assigned a significance of 1 were whereas beaches with a significance of 5 were 5 or more kilometres away.

This form of ranking provides an indication of the level of service that the beach may provide. It did not account for visitors from further afield, rather it provides an accessibility ranking. Figure 42 presents the relationship between beaches assigned a significance rating by DELWP (shown in bold) and the rating based on proximity significance.

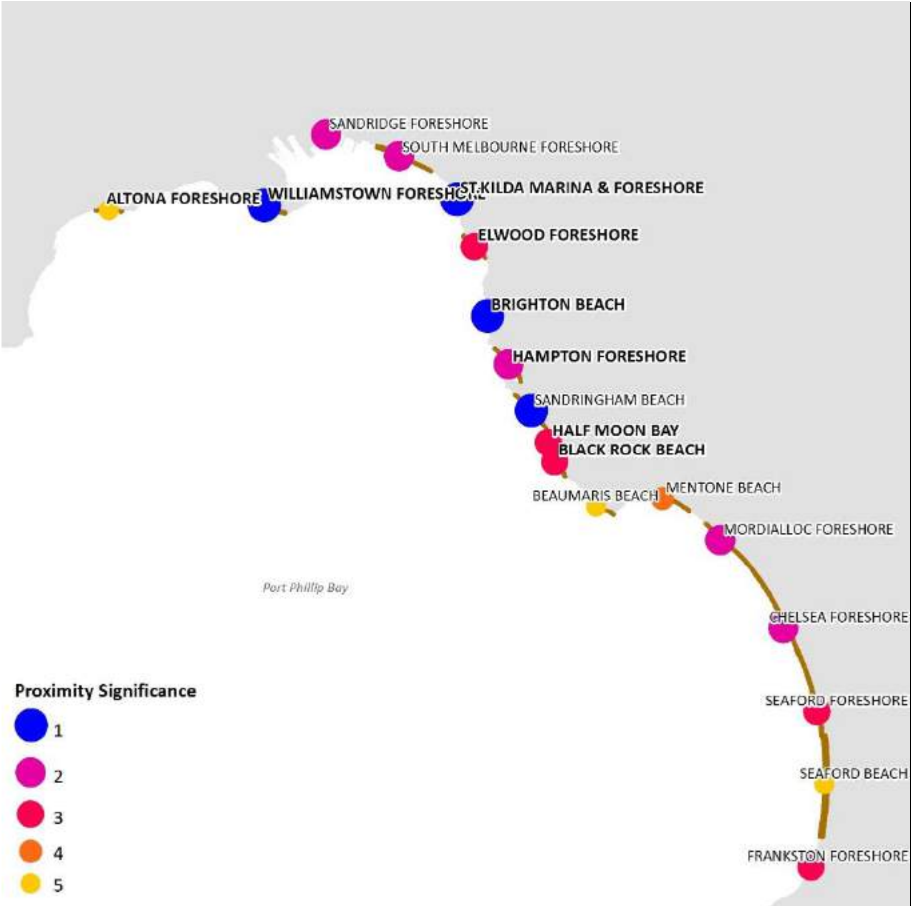

Figure 42. **Beaches along the north eastern coast of Port Phillip Bay ranked by proximity to population hubs.**

Further to this proximity analysis, the beaches can be reviewed in terms of their assessed Coastal Erosion Vulnerability rating. In the left panel of Figure 43, beaches that have 50% or less of their total area affected by High or Very High ratings are presented. The right panel presents beaches with greater than 50% of their total area affected by a High or Very High rating. All beaches were also ranked by their proximity significance and key significant beaches as identified by DELWP are emphasised in bolded text. Beaches with no area affected by High or Very High ratings are not shown although these beaches may have ratings that were assigned a rating in the moderate or less categories.

In terms of this basic evaluation relating to erosion factors alone, it could be construed that the beaches from Chelsea to Frankston Foreshore were of concern in regards to management or planning, as these beaches have a moderate level of service due to proximity to major population centres, and over 50% of beaches have a total area with a high or very high coastal erosion vulnerability rating.

Also of note due to possessing a very high proximity rating to population centres, moderate levels of coastal erosion and being a key significant beach as identified by DELWP, was St. Kilda Marina and Foreshore.

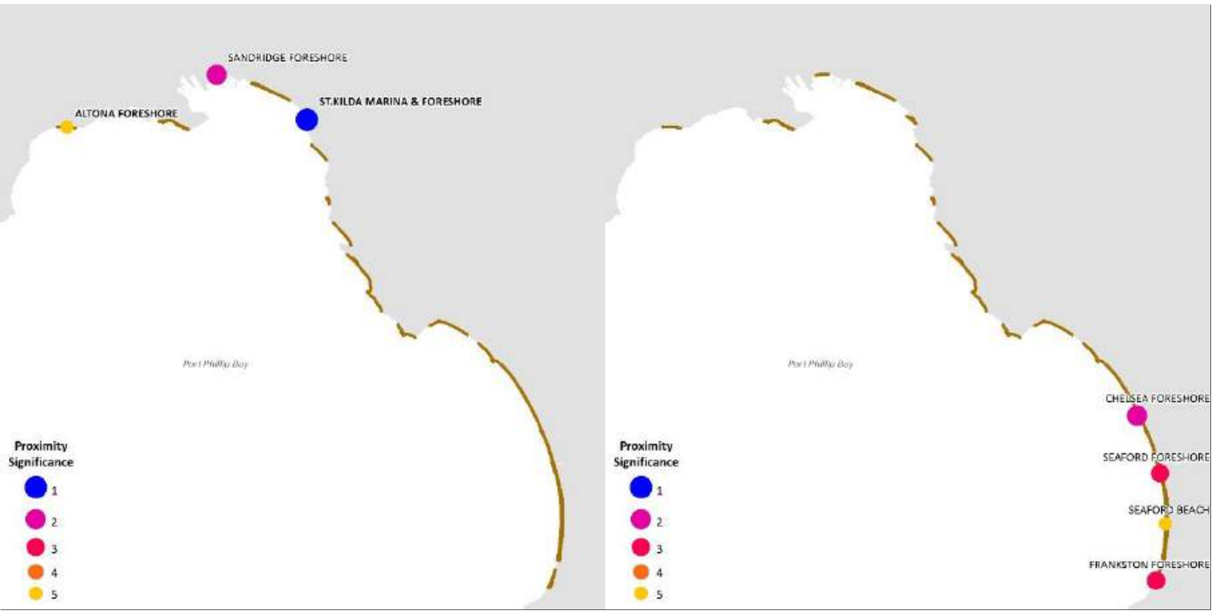

Figure 43. Beaches along the north eastern coast of Port Phillip Bay with assigned Coastal Erosion Vulnerability ratings. The left panel indicated beaches that have 50% or less of area affected by High or Very High ratings, and the right panel indicates beaches that have greater than 50% of area affected.

Beaches can also be reviewed in relation to inundation factors, such as SLR and STM. The left panel in Figure 44 presents beaches that have less than 50% of their total area affected by 20cm of SLR by 2040, whereas the right panel shows beaches that have greater than 50% of their total area affected. All beaches were again ranked by their proximity significance and key significant beaches are emphasised in bolded text.

The left panel shows multiple beaches with 50% or less area affected, with three showing a high proximity significance and five identified as a key significant beach. The right panel shows seven beaches with greater than 50% of their area affected. Of these one was in the highest proximity significance and three were key significant beaches.

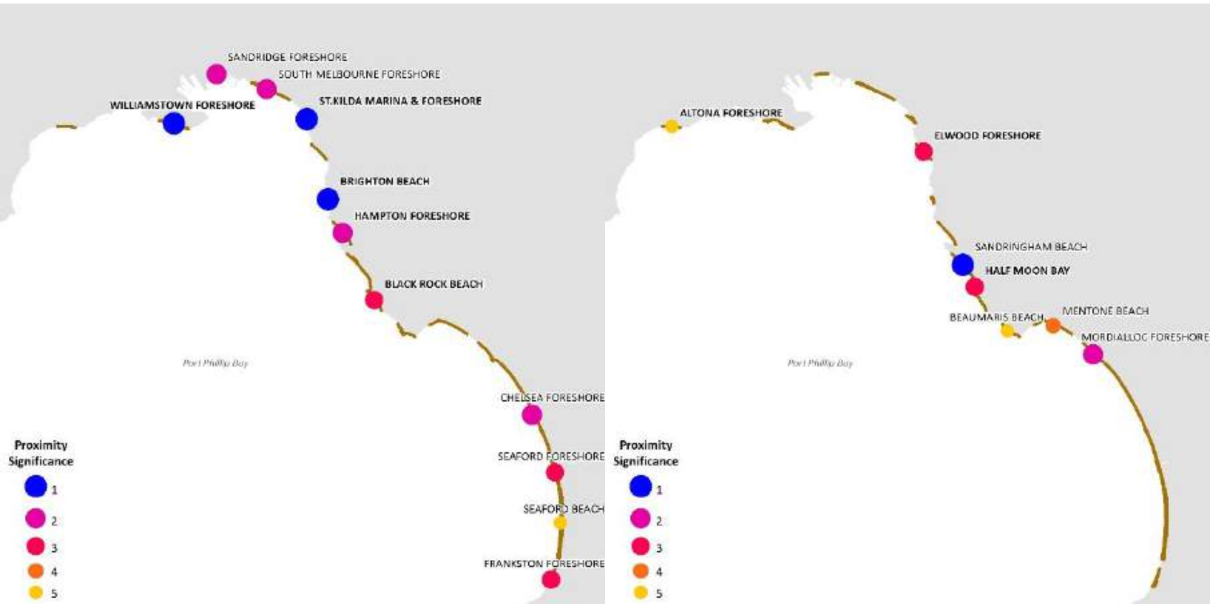

Figure 44. Beaches along the north eastern coast of Port Phillip Bay with assigned Inundation Scores for SLR in 2040. The left panel indicated beaches that have 50% or less of area affected by SLR, and the right panel indicates beaches that have greater than 50% of area affected.

When SLR in 2040 is considered, beaches such as Sandringham can be singled out due to their proximity to major population hubs and having over 60% of its total area being affected by SLR. Elwood Foreshore was evaluated to be similarly affected.

Based on both coastal erosion vulnerability and SLR, beaches such as Brighton, Elwood and Sandringham can be highlighted as beaches of concern for management and planning concerns.

The stretch of coast in the west from Torquay to Kennet River was identified to have multiple beaches and associated SLSC, with a few key significant beaches such as Fairhaven Foreshore and Bells Beach (Figure 45).

Figure 45. Significant and local beaches and SLSC along the surf coast region. Significant beaches have emphasised label text.

The significance of these beaches can be further highlighted through the assessment of the proximity to major population hubs. Figure 46 presents this proximity significance for the same selection of beaches. Using the 1 to 5 scoring system, based on the distance of these beaches from population hubs the majority were ranked 3 or lower, apart from Thirteenth Beach. From this proximity significance, a few beaches that may possess a higher service level can be singled out as having a higher maintenance or planning priority. These include identified significant beaches like Bells Beach and Fairhaven Foreshore, as well as locally significant beaches, like Kennet River and Wye River Foreshores.

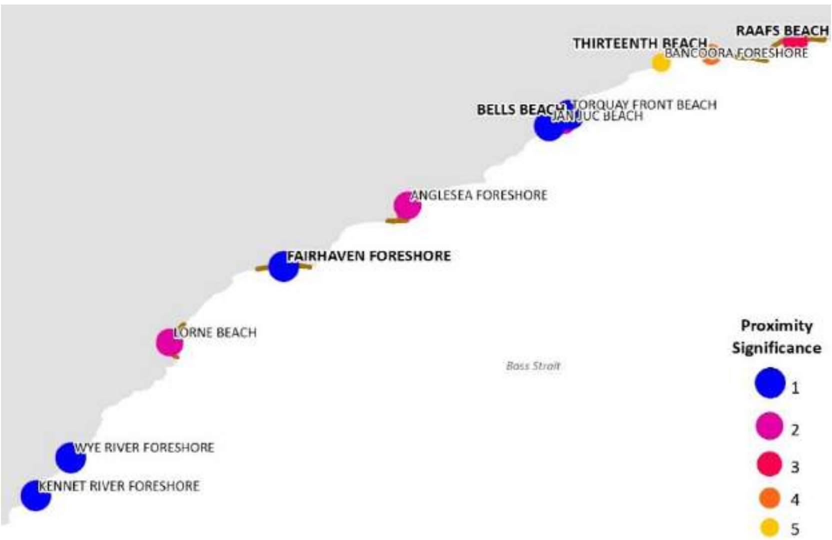

Figure 46. Beaches along the surf coast ranked by proximity to population hubs.

Further to this proximity analysis, beaches can be assessed in terms of their Coastal Erosion Vulnerability rating. In the left panel of Figure 47, beaches that have 50% or less of their total area affected by High or Very High ratings are presented. The right panel identifies beaches with greater than 50% of their total area affected. All beaches were also ranked by their proximity significance and key significant beaches are again identified in bolded text. Beaches with no area affected by High or Very High ratings are not shown.

The left panel shows multiple beaches with 50% or less area affected by High or Very High Coastal Erosion Vulnerability rating. The right panel shows only Raafs Beach with greater than 50% of its area affected by coastal erosion.

Figure 47. Beaches along the surf coast with assigned Coastal Erosion Vulnerability ratings. The left panel indicated beaches that have 50% or less of area affected by High or Very High ratings, and the right panel indicates beaches that have greater than 50% of area affected.

Figure 48 presents the findings in relation to inundation factors, such as SLR and STM for these beaches along the surf coast. The left panel in Figure 48 presents beaches that have less than 50% of their total area affected by 20cm of SLR by 2040, and the right panel shows beaches that have greater than 50% of their total area affected. All beaches were also ranked by their proximity significance and key significant beaches are again emphasised in bolded text.

The left panel shows six beaches with 50% or less area affected, with one showing a high proximity significance and three identifies as a key significant beach. The right panel shows seven beaches with greater than 50% of their area affected. Of these four were in the highest proximity significance category and one was a key significant beach.

In terms of the likely impacts of SLR in 2040, beaches such as Bells Beach, Jan Juc and Torquay can be singled out due to their proximity to major population hubs and having over 50% of its total area potentially being affected by SLR.

Fairhaven beach in contrast, whilst identified as a key significant beach, was assessed not to be highly impacted in relation to Coastal Erosion Vulnerability ratings or Inundation Factors.

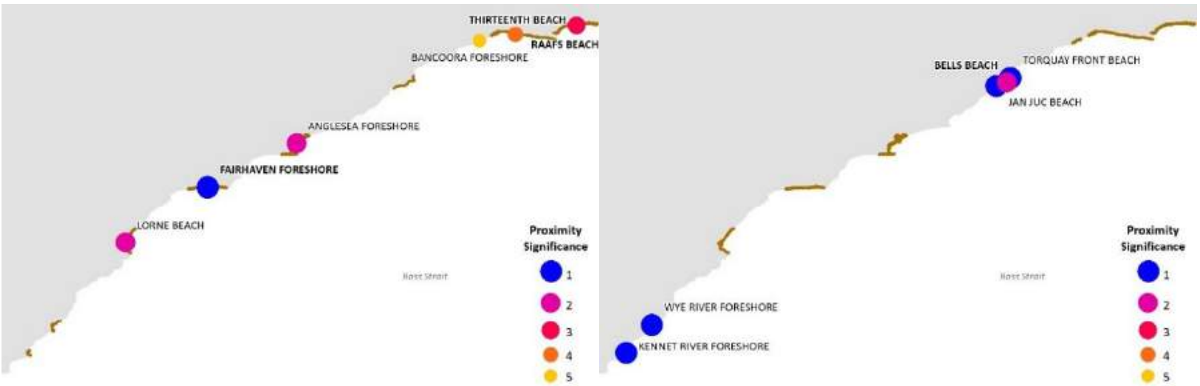

Figure 48. Beaches along the surf coast with assigned Inundation Scores for SLR in 2040. The left panel indicated beaches that have 50% or less of area affected by SLR, and the right panel indicates beaches that have greater than 50% of area affected.

Coastal Erosion Vulnerability ratings were assessed to be significantly higher along the eastern section of the Victorian coastline, into the Gippsland Lakes Region, than in the central and west zones. This can be principally attributed to sandy type coastlines with a high degree of exposure and not too many adaptive measures to mitigate effects. Figure 49 shows the Ninety Mile Beach Region of this coastline which includes Seaspray and Woodside Beaches. Ninety Mile Beach was considered a key significant beach due to tourism. Based on the proximity analysis the Ninety Mile Beach and Woodside Beach are rated to have a low proximity significance. Conversely Seaspray has a high proximity significance.

All three beaches were assessed to have greater than 50% of their total area assigned a High or Very High Coastal Erosion Vulnerability Rating. All three beaches will also be affected by SLR into 2040.

Figure 50 presents the Coastal Erosion Vulnerability score as assigned across the entire study areas. The red colour along the coast depicts a very high score and the orange a score of high.

In context to a management and planning perspective, these results can provide a good indication where to focus further investigation.

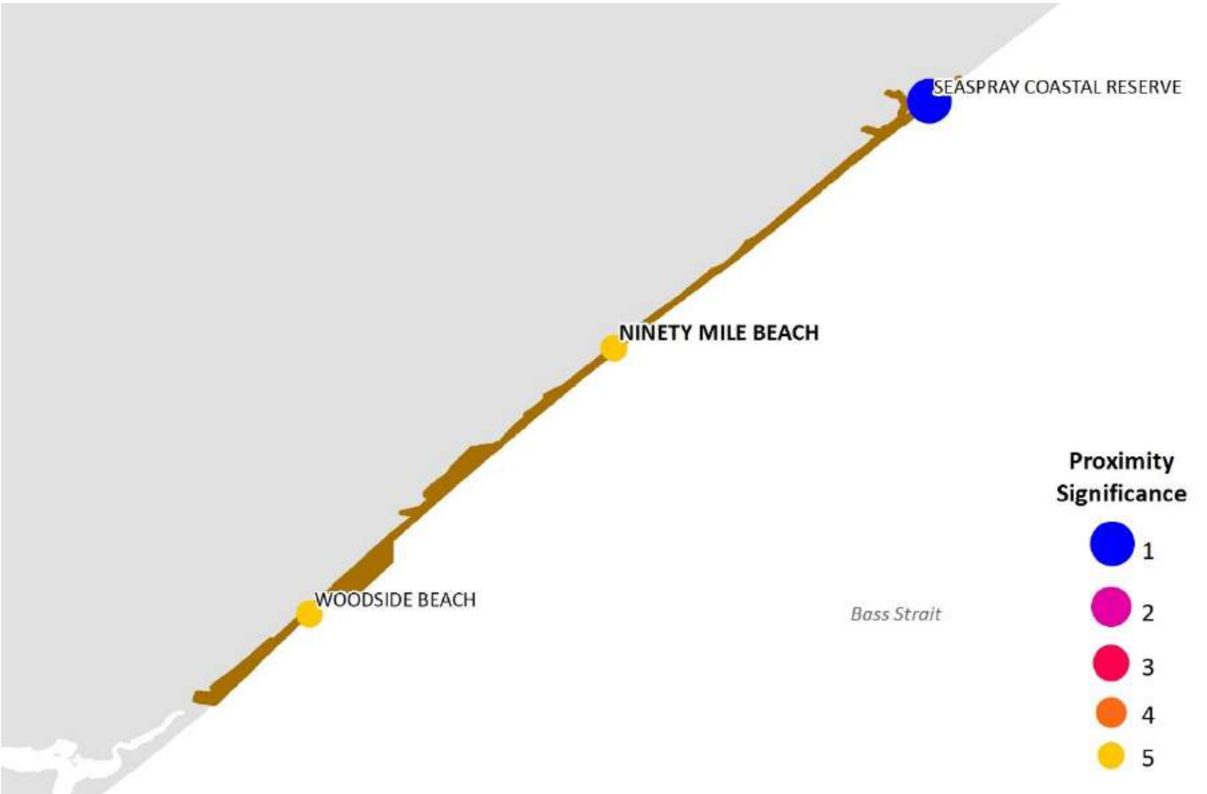

Figure 49. Beaches along the Ninety Mile coast with assigned Coastal Erosion Vulnerability ratings indicating beaches that have 50% or more of area affected by High or Very High ratings.

Figure 50. Beaches along the Ninety Mile coast with full study area Coastal Erosion Vulnerability ratings.

PART 6 – APPLICATION OF STUDY RECOMMENDATIONS

11. Sensitivity Analysis Application

One of the main recommendations arising from the Spatial Vision Coastal Climate Change Impact Assessment and the final project workshop was the implementation of sensitivity testing of the components and attributes within the state-wide modelling framework as established by Spatial Vision. To this end, a Sensitivity Analysis (SA) was undertaken on the components of the framework applied, the results of which are summarised in this section.

The inputs used in the original study were derived from an extensive literature review and several expert workshops to identify what influences the Coastal Erosion Vulnerability ratings and the component inputs within Exposure, Sensitivity and Adaptive Capacity.

The full details on applying this sensitivity analysis on the original framework are documented in the Coastal Climate Change Assessment Sensitivity Analysis report. The key findings of this sensitivity analysis were several implementable recommendations that can be actioned to improve the overall results of the State-wide impact assessment.

The results of applying these refinements based on the sensitivity analysis findings are presented in this section.

11.1 Analysis of Sensitivity Analysis recommendations

The key issue identified with the initial application of the model was the potential over-representation of Exposure elements, and under-representation or importance assigned to Sensitivity components of the model. To address this the Exposure elements were reduced effectively by one component (from 6 to 5), and the Sensitivity rating was given greater weight by applying a power of 1.5 to its original score.

Adjustments to the model implemented based on the outcome of Sensitivity Analysis work therefore involved:

- Adjustment of the Sensitivity component to retain the $x^{1.5}$ influence level.
- Retain coast type as an attribute in Exposure.
- Grouping of attributes in the Exposure component
  - Wave Height and Wave Energy to be averaged out.
  - The remaining four attributes and this wave climate layer to form the Exposure output.

The key adjustment made within the Exposure component of the model used was to group the two wave attributes of height and energy into a single wave climate attribute. The data spread for this adjusted Exposure rating is presented in Figure 51. Here the open coast and re-entrant data distribution were compared against the full coast. The result of this adjustment was to shift the low ratings for the re-entrant area of the coast to more moderate ratings and reduce the high rating assigned to some areas of open coast.

Hence five rather than six effective attributes were applied in the model to assign an exposure rating.

A comparative analysis was undertaken along the coastline at key reference sites using these updated adjustments.

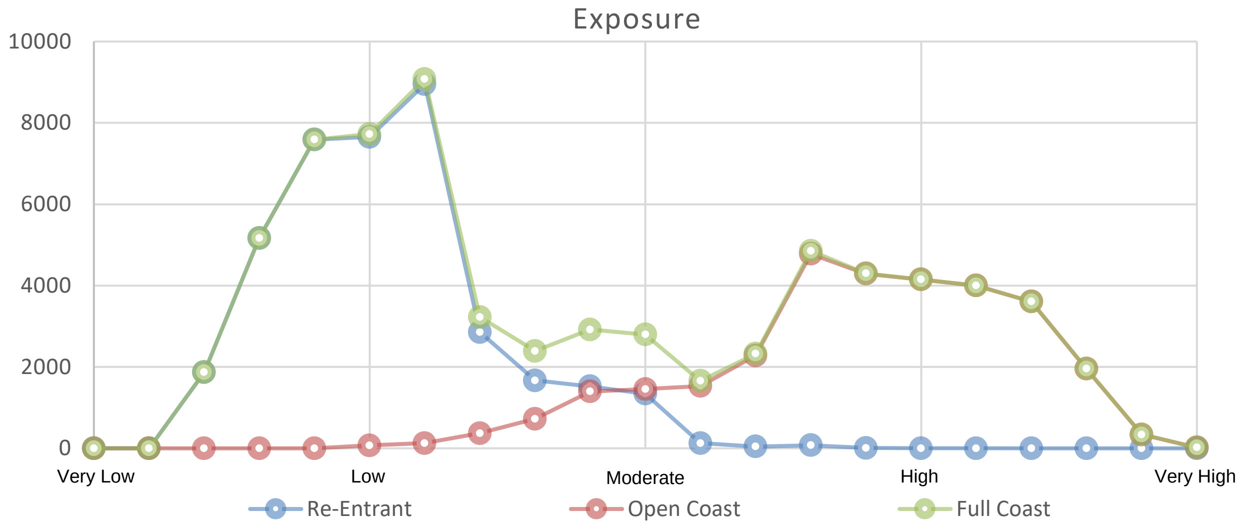

Figure 51. **Coastal Exposure rating data spread with grouped wave climate. Compared against coastal segments defined as open coast and re-entrant.**

This adjusted Exposure score was then applied into final Coastal Erosion Vulnerability ratings. The revised coastal erosion vulnerability rating also incorporated a revised sensitivity component. To increase the presentation of sensitivity components it was proposed that a power be applied to the original sensitivity score. Adjustment to the Sensitivity component involved use of applying a power or exponent of $x^{1.5}$ and x^2.

This refinement to increase the contribution made by the sensitivity value was undertaken in lieu of additional Sensitivity attribute inputs to simulate what may possibly occur if more inputs were added to increase the impact of Sensitivity.

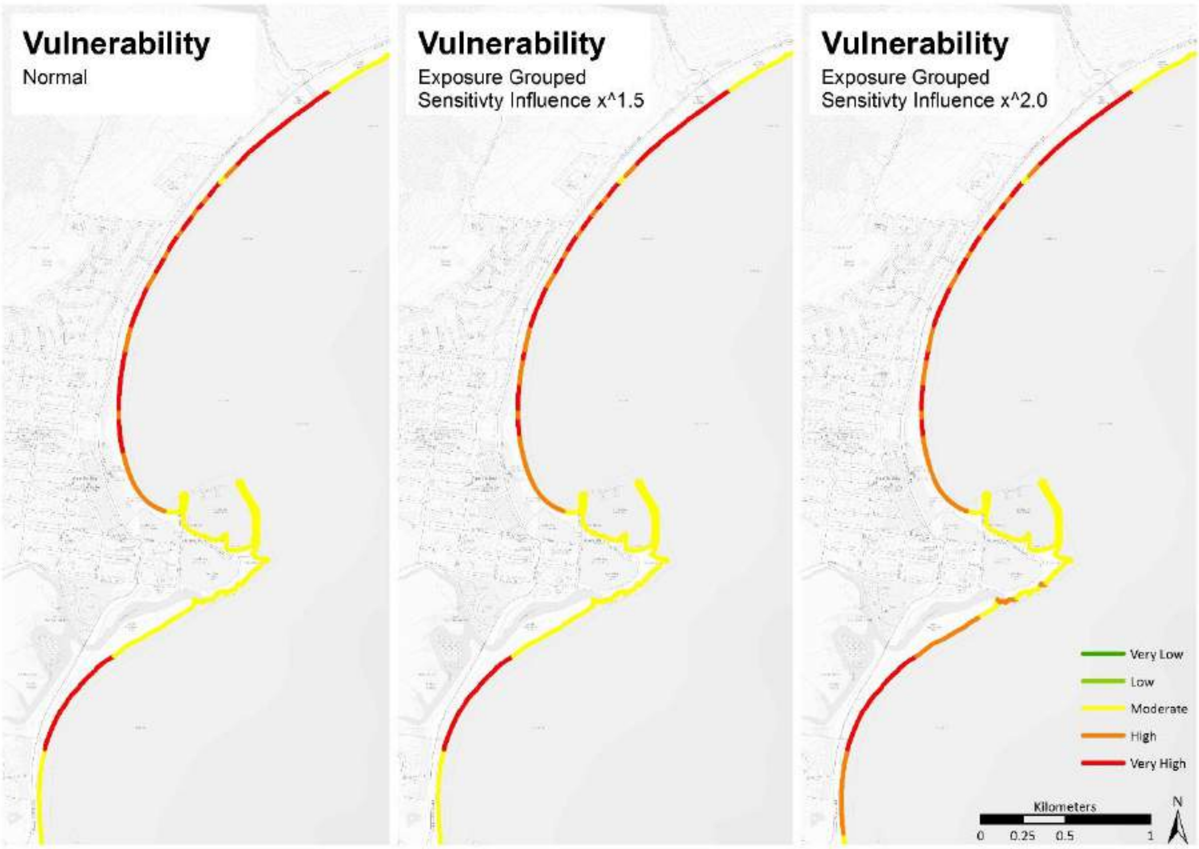

Figure 52. **Coastal Erosion Vulnerability comparison at Apollo Bay. Unadjusted (left panel), grouped wave climate and Sensitivity influence $x^{1.5}$ (centre panel), grouped wave climate and Sensitivity influence $x^{2.0}$ (right panel).**

Figure 52 presents the results for Coastal Erosion Vulnerability in the Apollo Bay region with the original unadjusted rating compared against two alternative approaches considered in the exponent level adjustments. In the centre panel where wave climate was grouped (by combining wave height and energy and dividing by 2) and Sensitivity increased to $x^{1.5}$, there was minimal change. Only some rating adjustments along the Apollo Bay foreshore. In the right panel with Sensitivity increased to x^2, there was a large increase in the moderate ratings in the Marengo Bay region up to the Apollo Bay headlands.

Figure 53 presents these same comparisons in the Western Port Bay Region. This result shows a more pronounced differentiation between the unadjusted original and the grouped ware climate together with adjusted Sensitivity rating options. In the centre panel, with a Sensitivity increased by $x^{1.5}$, there was a shift to more moderate and high Vulnerability ratings across the region. This was more noticeable when Sensitivity was adjusted to an x^2 influence, with the majority of this area assigned either moderate or high ratings.

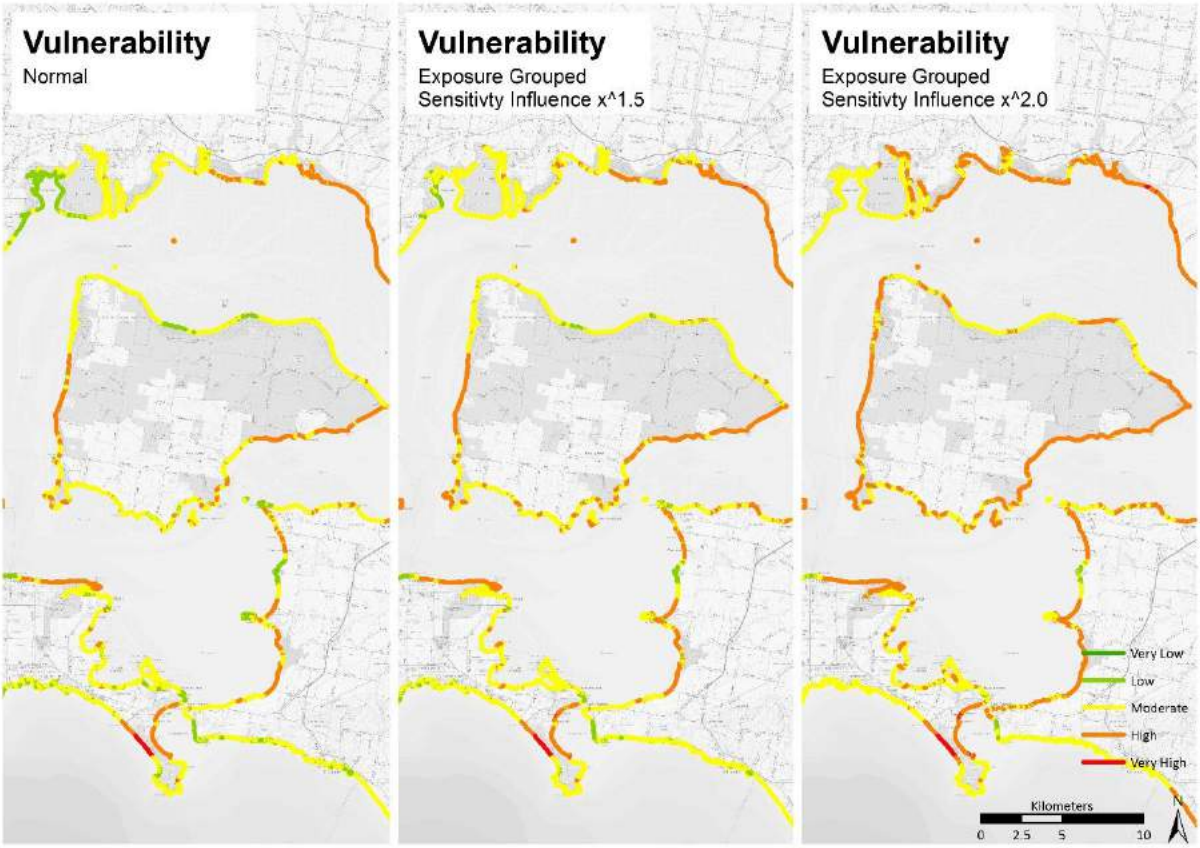

Figure 53. Coastal Erosion Vulnerability comparison at Western Port. Unadjusted normal (left panel), grouped wave climate and Sensitivity influence $x^{1.5}$ (centre panel), grouped wave climate and Sensitivity influence $x^{2.0}$ (right panel).

This analysis confirmed that the proposed refinements to the calculation of a vulnerability rating had the desired effect in providing a more suitable distribution in the final vulnerability ratings.

In summary, to account for additional Sensitivity components it was suggested to increase the influence of this component using an exponent of $x^{1.5}$, (since increases to x^2 were viewed to over emphasise Sensitivity), while at the same time reducing the influence of Exposure (by combining wave energy and height in the original process into the one wave climate variable). Hence, keeping to the slightly adjusted Sensitivity would boost this component in lieu of additional inputs, while accounting for the adjustments in Exposure.

11.2 Application of Sensitivity Analysis outcomes to Study Area

The revised coastal erosion vulnerability score assigned to the coastline, where the wave energy and height attributes were grouped and the Sensitivity put to an exponent power of $x^{1.5}$, was reapplied to the full study area. This was again applied to each of the 23 Sediment Compartments where the translation decays were applied.

Figure 54 presents the result of applying this inland translation of Coastal Erosion Vulnerability in the Apollo Bay region with the original rating compared against the revised rating applying the results of the sensitivity analysis.

In comparison to an original translation, the right panel, where wave climate was grouped and Sensitivity increased to $x^{1.5}$, significant changes were noticed. This figure shows how for the Marengo Bay area south of Apollo Bay the adjusted vulnerability resulted in inland ratings in the very high and high ratings continuing further inland than the original process.

Figure 55 presents these same comparisons in the Western Port Bay Region. This provided a more pronounced differentiation between the original and adjusted results based on the Sensitivity analysis findings. The adjusted right panel indicated a shift to more moderate and high ratings across the region. This was more noticeable into the north at Tooradin where high and moderate ratings were identified to continue inland to the 1,500m distance mark.

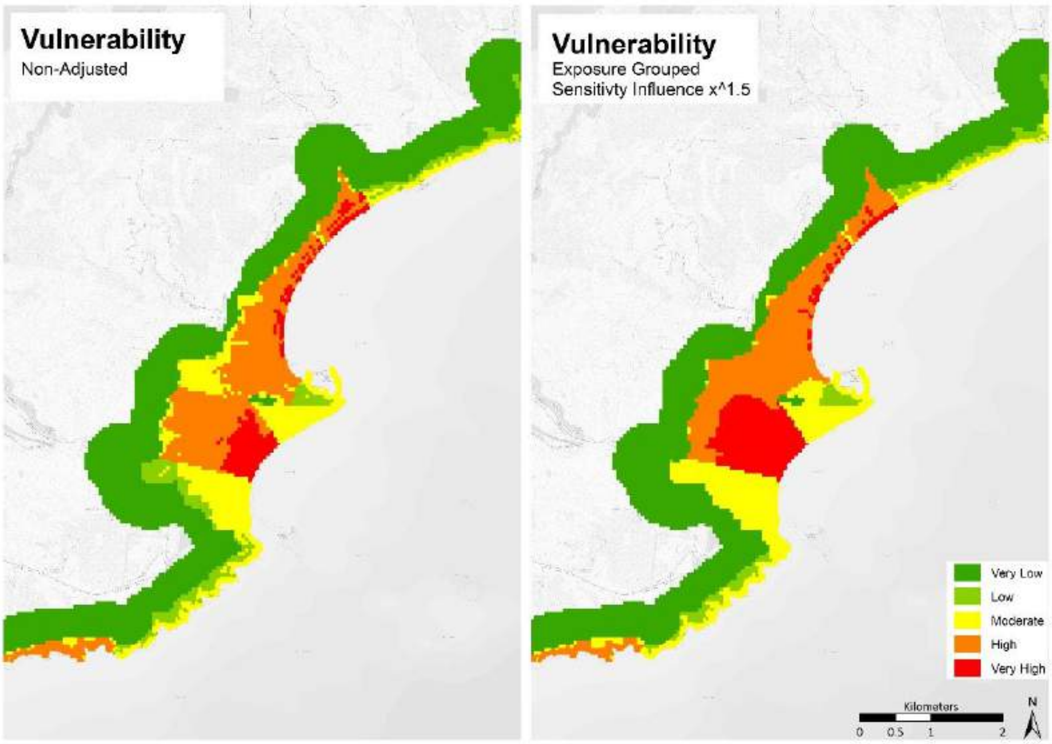

Figure 54. Coastal Erosion Vulnerability inland decay translation comparison at Western Port. Unadjusted normal (left panel), grouped wave climate and Sensitivity influence x1.5 (right panel).

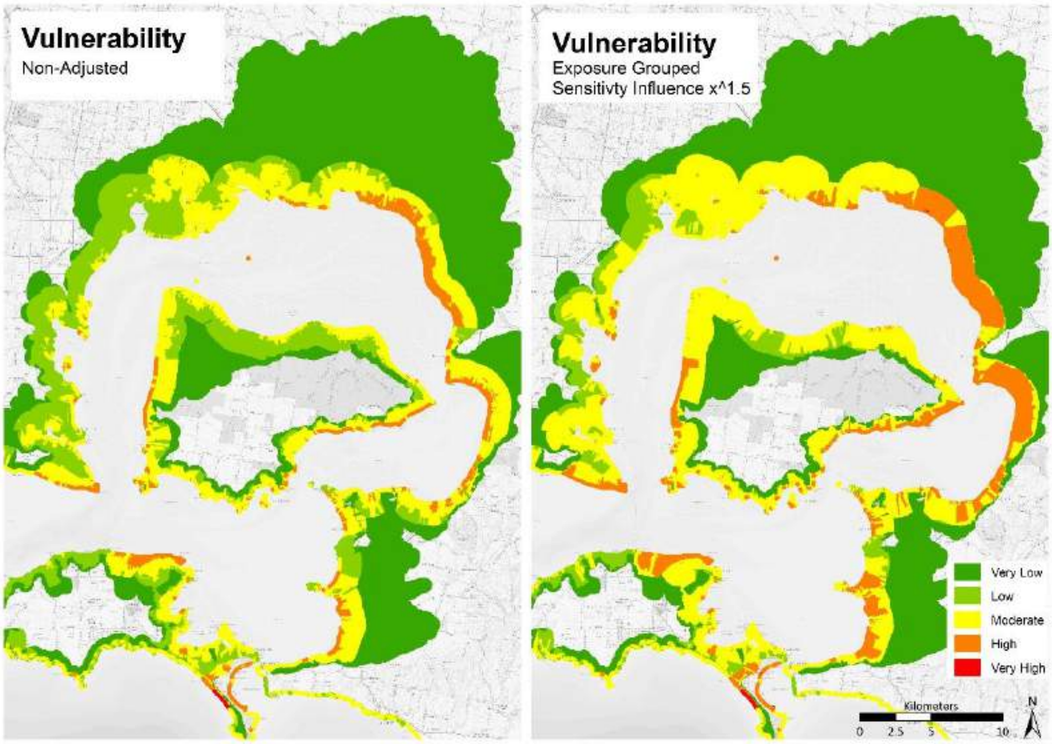

Figure 55. Coastal Erosion Vulnerability inland decay translation comparison at Apollo Bay. Unadjusted normal (left panel), grouped wave climate and Sensitivity influence $x^{1.5}$ (right panel).

12. Gippsland Lakes Application

A second key recommendation arising from the Spatial Vision Coastal Climate Change Impact Assessment and the final project workshop was to review the findings against other studies, particularly the third pass \ Local Coastal Hazard Assessments (LCHA) for four locations along the Victorian Coastline: Port Fairy, Bellarine Peninsula and Corio Bay, Westernport and Gippsland Lakes

The higher level objective of these LCHAs was to provide information for relevant agencies and stakeholders to plan for climate risks along the coast by generating detailed mapping and assessment analysis into erosion and inundation hazards. These assessments were to provide a basis for planning for and mitigating impacts of storm surges and sea level rises into the future.

The Local Coastal Hazard Assessment for the Gippsland Lakes and 90 Mile Beach was undertaken by Water Technology and was finalised in April of 2014. The principal aim of the LCHA was to identify and assess the coastal erosion and inundation hazards within the Gippsland Lakes and 90 Mile Beach region, both under current and future climate conditions.

The coastline identified in the SmartLine dataset did not include the Gippsland Lakes but rather only the open coast sections of the region. Hence, there was significant interest in including information from the LCHA into the state-wide second pass assessment. This was investigated as part of the review process, the results of which are documented in this section.

12.1 Definition of the Gippsland Lakes Shoreline

One notable recommendation that arose from the assessment of the Gippsland LCHA in relation to the Spatial Vision assessment was associated to the definition of the Victorian coastline, in particular the Gippsland Lakes region. Currently for Gippsland, only the coastline in this area was defined. Although the inland lakes of King, Victoria, Reeve and Wellington are freshwater environments, there are major interactions between the lakes and open coast. The coastal outer barrier and how it reacts to sea level rises and storm surges has implications for the lakes. Hence erosion and inundation modelling using an updated coastline was viewed to provide a more reasonable and useful view of coastal erosion vulnerability and inundation impacts.

The LCHA undertaken by Water Technology considered erosion along the Gippsland Lakes shoreline in relation to erosion susceptibility. Figure 56 presents the results for the two highest erosion susceptibility groupings, as determined in the LCHA.

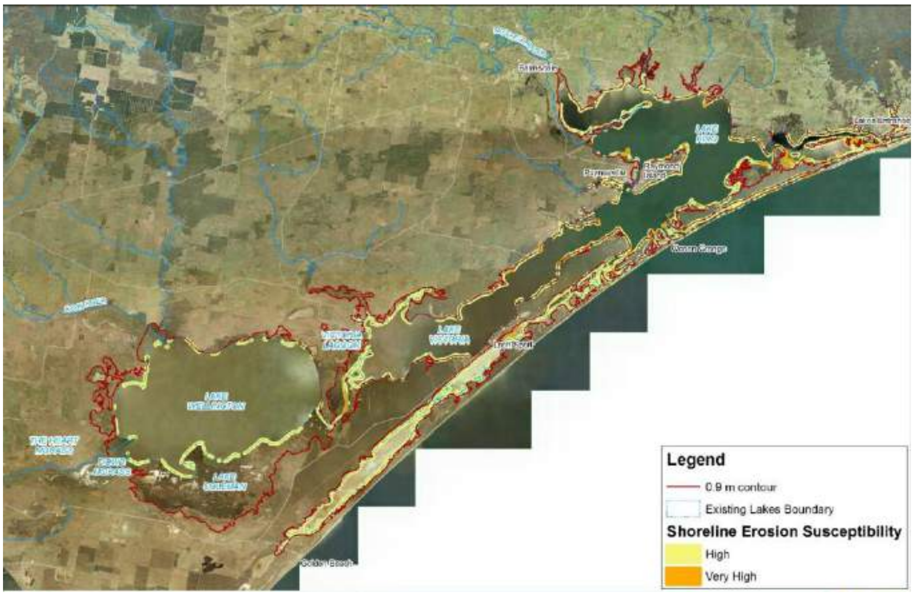

Figure 56. Gippsland Lakes Shoreline Erosion Susceptibility

Source: Water Technology (2014)

Given this detailed view of erosion susceptibility for the Gippsland Lakes, it was decided that it was of value to incorporate this study into the state-wide assessment process if practical.

12.2 Comparison of Local Coastal Hazard Assessment and Coastal Impact Assessment

There were a number of key similarities that allowed for a comparisons between the LCHA and state-wide second pass assessment methodologies. The Gippsland LCHA used a different approach to assess coastal erosion impacts on the open coats, and within the Gippsland Lakes. The approach taken for the Gippsland Lakes shoreline is presented in Figure 57.

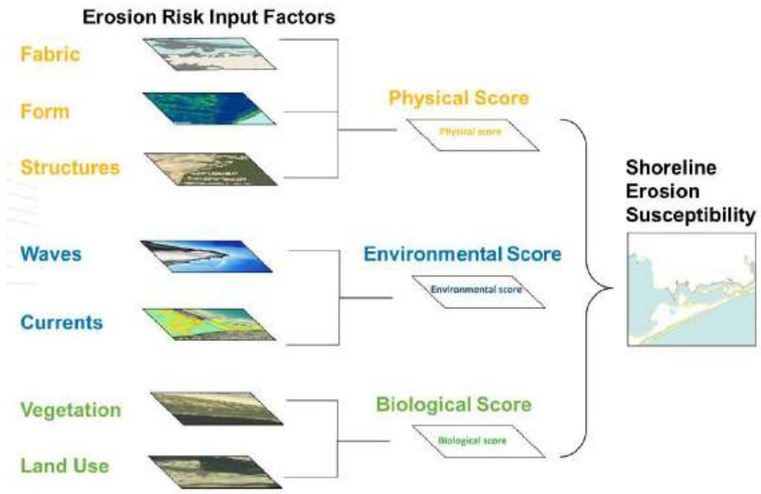

Figure 57. Conceptual process for Gippsland Lakes Local Coastal Hazard Assessment shoreline erosion susceptibility assessment

Source: Water Technology (2014)

This approach included several forcing factors that were identified as influencing shoreline erosion covering physical, environmental and biological factors. In reviewing how the LCHA findings could be applied or incorporated into the state-wide second pass assessment, these parameters we cross referenced to attributes in the second pass assessment. Table 27 presents the observed relationship between the LCHA parameters and those applied in the state-wide second pass assessment.

Table 27. Gippsland Lakes Local Coastal Hazard Assessment layers linked to Spatial Vision Coastal Impact Assessment

Gippsland LCHA	Spatial Vision Coastal Impact Assessment	
	Attribute	Component
Physical		
Geology	Erodibility Sediment Sensitivity	Sensitivity
Landform	Erodibility Sediment Sensitivity	Sensitivity
Artificial Structures	Engineered Structures	Adaptive Capacity
Environmental		
Wave climate – height and frequency	Orientation Fetch Wave Height Wave Energy	Exposure
Currents	Wave Energy	Exposure
Biological		
Coastal Vegetation	Coastal Vegetation Intertidal Vegetation	Adaptive Capacity
Land Use	Coastal Vegetation	Adaptive Capacity

For each factor identified and applied in the LCHA, a range of datasets were collected and scored appropriately. Datasets were then combined for each theme and weighted to form a final erosion susceptibility score for the lakes shoreline.

This method was extremely similar to that applied in the second pass state-wide assessment. The essential difference is that the second pass assessment arranges attributes into Exposure, Sensitivity and Adaptive Capacity components, and multiplied these components to derive an overall erosion vulnerability, whereas the Gippsland LCHA provisions organised parameters into Physical, Environmental and Biological factors.

Furthermore, the LCHA applies several attributes that were not present in the second pass assessment framework.

Due to absence of several attributes in the Gippsland model, such as bathymetric profile and presence of reefs, a conservative approach was taken when applying the Gippsland Lakes shoreline into the state-wide framework. This involved:

- Very High ratings in the LCHA being translated back into the mid-point between high and very high in the LCHA.
- High ratings being scored to the mid-point between moderate and high.
- All other ratings in the LCHA being scored a low rating.

12.3 Application of the Shoreline

Using the translation rules outlines, the Gippsland Lakes shoreline as defined in the LCHA was incorporated or appended into the state-wide framework. The resultant Vulnerability rating attributed to this shoreline was assigned inland using the decays applied in the state-wide study. Figure 58 presents a direct comparison of the application of this process in Lake Victoria, Lake Reeve and Lake King. The left panel presents modelled Vulnerability without incorporating the Gippsland LCHA data, where the inland translation decay prevents the Vulnerability providing any scores inland from a distance of 1500m. The right panel presents the erosion vulnerability assigned when the LCHA information and shoreline is incorporated.

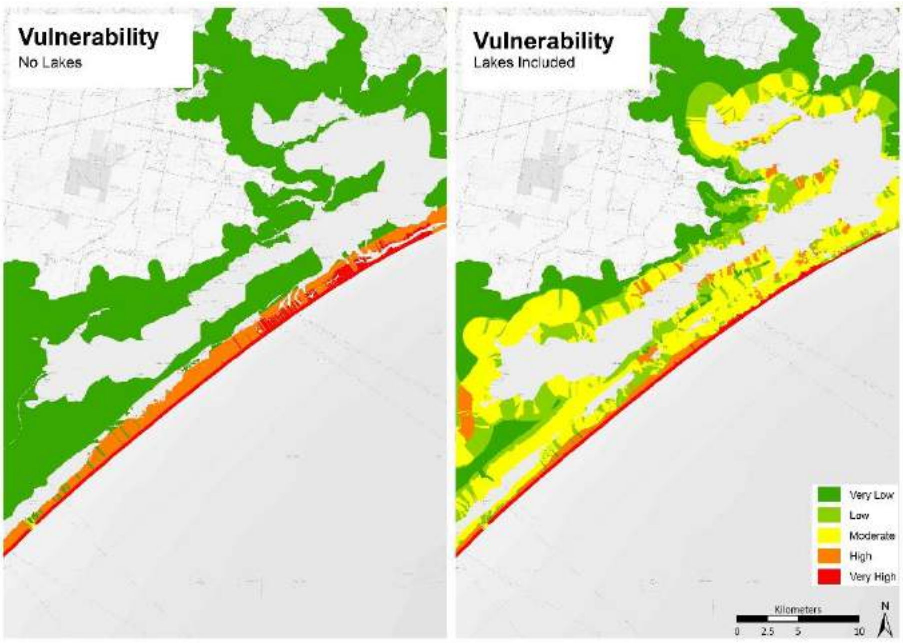

Figure 58. Comparison of Coastal Erosion Vulnerability with no lake shoreline (left panel) and applied lake shoreline (right panel)

Figure 59 provides a more detailed view of the central Lake King and Lake Reeve region of Gippsland. This view demonstrates the interplay and transition between the coastline and shoreline and how both shorelines in the inland translation decays meet at a central point.

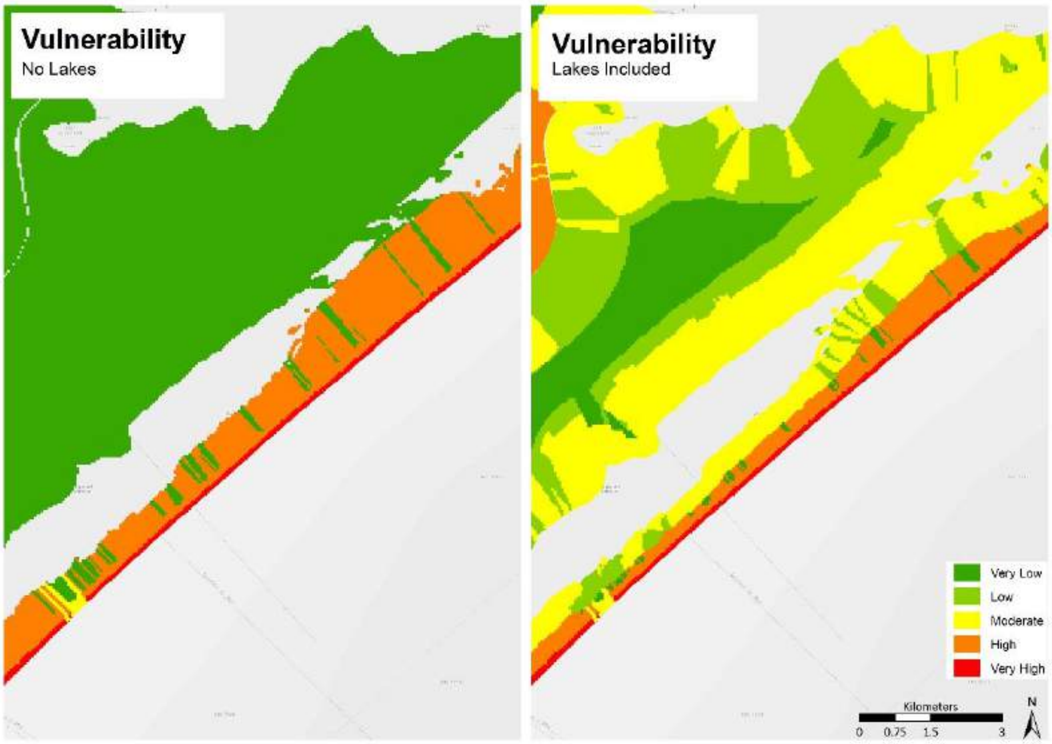

Figure 59. Close up comparison of Coastal Erosion Vulnerability with no lake shoreline (left panel) and applied Lake Shoreline (right panel).

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Appendix 1: Terms and Definitions

Storm Surge: relates to the temporary inundation of a unit of land along the coast due to factors such as wind and waves.

Inundation: refers to the coastal process in which storm surges and/or extreme wave heights driven by coastal winds can cause temporary flooding along the costal margins inland from the ocean.

Stability: refers to the susceptibility of coastal areas to physical change, including erosion, slumping and other such impacts. In this vein it relates to a narrower term of reference than sensitivity in that it only deals with erosion alone and not inundation. Hence, coastal stability depends on landform geology/geomorphology and not upon topography.

Erosion/Erodibility: is the natural process of the wearing-away of land by the action of natural forces. In a coastal setting these actions can include the movement of material by wave action, currents or wind. Erodibility is in reference to the coast and how sensitive it may be to these coastal processes. This attribution has been embedded into the SmartLine dataset and is a reflectance of the coastal geomorphology.

Instability/Zones of Potential Instability: refers to portions of the coastline identified as being potentially unstable due to erosion under a scenario combining sea-level rise and climate forcing. The term "Zone of Potential Instability" was coined after the broad assumption that all coastal areas would recede in the face of climate change was challenged in light that some areas would accrete sediment under certain scenarios. It was decided that instead of modelling coastal recession, it would be preferable to designate Zones under a worst case assumption of recession for all shorelines types. (See Cechet, R. 2012. Impacts of Climate Change on Human Settlements and Other Nationally Significant Infrastructure in the Coastal Zone).

Coast/Coastline: for the purposes of this study is the delineation between the water and land. This includes all geological and geomorphological

Fetch: The maximum direction over water that winds of a given direction can generate waves.

Wave Energy: refers to the Wave Energy Flux or Wave Power Density. It is a measure of the available power in the wave, calculated as the kilowatts per metre of wave crest width (kW/m).

Wave Height: Wave height, or Significant Wave Height, is typically defined as the average height of the largest one third of a wave. Simply can be related back to the mean breaker wave height at the beach.

LCHA: is a Local Coastal Hazard Assessment – this is a detailed coastal hazard study for a given area. Is comparable to a third pass assessment, where local scale data and conditions are considered, rather than regional or catchment scale data.

AEP: refers to the Annual Exceedance Probability – the likelihood or probability that a given level will be exceeded in any one year. Used primarily in relation to LCHA and detailed studies.

Appendix 2: Victorian Coastline Dataset

Victorian Coastline Dataset – SmartLine_Victoria_2008

SmartLine_Victoria_2008

This dataset is based on a process used to generate the 0m and 0.5m contours contained in the VicMap Elevation Coastal DEM and Contours product derived using LIDAR returns acquired between September 2007 and September 2009. The process of enhancing the missing areas of coastline in these LIDAR derived datasets, or enhancing the area around ports, with lines interpreted from aerial photography involved applying the same definition of the coast applied in the VicMap Elevation Coastal product (Figure 60). Given the time differences in LIDAR returns it is clear that the coastline did not consistently depict high or low tide, but rather a general or average view of the coastline (or possibly a mean sea level) on a state-wide basis. A definition of what constituted the coast was required in relation to substantial man-made structures along the coast. The VMSH_Framework dataset was used as a guide to determine which of these structures should be incorporated into the coastline. Where the VMSH_Framework dataset was inconclusive, or there were significant discrepancies, substantial man-made structures greater than 20m in width were incorporated into the coastline.

The coverage of the coastline dataset is consistent with that applied in the capture of jetties and boat ramps in that it includes sections of coastal rivers and water bodies extending away from the coast. The distance from the main coast for which the coastline was reviewed and refined was largely determined by a logical boundary based on where development activities appeared to finish using the best available aerial photography. Hence, the coastline dataset includes areas such as around the Gippsland Lakes, or marina developments around Port Phillip Bay including Patterson River. It also includes islands

Key issues encountered in the creation of the SV_Coastline_2008 layer are largely outlined in the processes and dataset description provided in early sections. In summary, they include:

- Ensuring consistency in the interpretation of the coast based on the existing 0m and 0.5m contours derived from LIDAR returns; and
- Ensuring the coastline created was consistent with the jetty, boat ramp and protection structure information depicted in other SECAP datasets to ensure a suitable depiction of coastline infrastructure can be generated (in the context of the coast).
- Review of MGA Zone 54 0m contour line when this becomes available in the future and replacement of current 0.5m contour if required

Three main issues were identified with the 0m contour derived from LIDAR returns:

- Contours were incomplete with large sections of coast completely missing in the western section of the state (MGA Zone 54)
- Other sections of the coast included significant 'noise', particularly in areas of significant tidal movement, such as around mud-flats and shallow coastal lakes; and
- Areas of the coast with built infrastructure or significant boating activity were erroneously represented due to interpolation and smoothing processes undertaken to generate the surface model and contours.

Figure 60. Map view showing difference in detail between the Coastline 2008 dataset that have been used in this study and the National SmartLine dataset.

Appendix 3:
Climate Future Considerations

Climate Future Considerations

Available Climate Data

Available Climate Models and Time frames

Climate projections, termed CMIP5 projections, were released by CSIRO in March 2014 and made available for use in this project.

The 'Draft Projections for Australia's NRM Regional Data Delivery Brochure' prepared by CSIRO which accompanied this information outlines the background to the climate scenario data provided. This draft brochure (Webb, 2014) states that:

CSIRO, in partnership with the Bureau of Meteorology (BoM), have developed climate change projections for Australia's natural resource management (NRM) sector. The projections have been developed to assist in sustainably managing Australia's natural resources in a changing climate.

Climate change projection data are usually based on output from climate models driven by various scenarios of greenhouse gas and aerosol emissions (IPCC, 2013).

The climate projections team from CSIRO and BoM have undertaken an assessment of the latest projections to give users access to the results, with accompanying guidance on which products are fit for purpose.

For the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013), the scientific community defined a set of four new scenarios, denoted Representative Concentration Pathways (RCPs). The RCPs provide standardised greenhouse gas concentration inputs for running climate models. Climate projections are available from model simulations using our RCPs: RCP8.5, RCP6, RCP4.5 and RCP2.6 (Moss et al., 2010, Van Vuuren et al., 2011) (Figure 9 in this report). These are named in accordance with the range of radiative forcing values (in watts per square metre), which are a measure of the level of influence these gases have on the Earth's energy balance. Each RCP is representative of a range of economic, technological, demographic, policy and institutional futures. RCP4.5 could be considered as a trajectory with moderate emission reductions, consistent with the lowest (B1) scenario of the IPCC SRES suite developed in 2000. RCP8.5 is similar to the highest (A1FI) SRES scenario. RCP2.6 is lower than the lowest SRES scenario. Therefore, the range of climate projections based on RCPs is broader than those based on the SRES scenarios

For the NRM climate projections, data from 16 to 40 climate models1 have been analysed from the Climate Model Intercomparison Project (CMIP5) (Taylor et al., 2012).

Webb (2014) also note that:

Users of climate projections are strongly advised to represent a range of climate model results in their studies and reports. CSIRO's Climate Futures approach has been developed to help capture the range of projection results relevant to their region (Whetton et al., 2012).

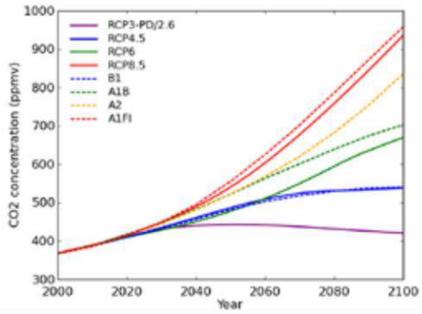

Figure 61. Relationship between four new scenarios, denoted Representative Concentration Pathways (RCPs), where RCPs provide standardised greenhouse gas concentration inputs for running climate models.

Climate considered for this project

In relation to the specific climate data provided by CSIRO for this project, the data provided includes projected climate changes (relative to the IPCC reference period 1986–2005), based on CMIP5 global climate models judged to perform well over Australia.

These interim projections were derived from global climate models from the Climate Model Intercomparison Project Phase 5 (CMIP5). They take the form of projected 20-year average changes relative to the 1986-2005 model averages. The data was underpinned by a Technical Report which has not passed the peer-review process yet. CSIRO note that these data would not normally be released until the review process is complete, but CSIRO recognises the value of providing interim projections at an early stage to selected stakeholders.

The data made available has been provided with its native grid resolution of ~135km. The data includes:

- Historical climatology: 1986-2005
- Future climatology's: 2021-2040, 2041-2060, 2061-2080, 2080-2099
- Change(absolute): future climate relative to 1986-2005
- Climate variables: Temperature minimums (Tmin), Temperature maximums (Tmax,), precipitation

Climate Change Scenarios

The specific climate data to be applied in this project have included projected climate changes (relative to the reference period 1961–1990, based on CMIP5 global climate models (ACCESS 1.0 model, proved by CSIRO/BOM) judged to perform well over Australia.

Climate scenarios to be considered in terms of carbon emission projections based on the CMIP5 climate model results provided by CSIRO have been:

- RCP 8.5 - Extreme scenario (in terms of future carbon emissions); and possibly
- RCP 4.5 - Moderate scenario (in terms of future carbon emissions).

Direct Climate Stressors

The direct climate stressors to be considered for use in this project ae:

- Mean Daily Maximum Temperatures (Tmax) for each season
- Mean Daily Rainfall (Precipitation) for each season
- Wind Speed (m/sec)

Climate Change Time Frames

The base line climate data for the CMIP5 climate projections was based on average climate variables for the period 1961–1990. For the purposes of this project the baseline year was identified as 1990. Hence, the 2090 time period was viewed to represent the 100 year timeframe scenario.

The years at which potential impacts have been assessed in this project based on emission scenario information provided in the CMIP5 climate model results from CSIRO were:

- 2030 (40 years from the baseline year)
- 2050 (60 years from the baseline year)
- 2070 (80 years from the baseline year)
- 2090 (100 years from the baseline year)

Climate scenarios considered in this project in terms of carbon emission projections based on the CMIP5 climate model results provided by CSIRO were:

- RCP 4.5 - Moderate scenario (in terms of future carbon emissions)
- RCP 8.5 - Extreme scenario (in terms of future carbon emissions)

In processing the CMIP5 Rainfall and Max Temp data provided by CSIRO, the project team expressed some concerns to the CSIRO with the RCP 4.5 emission scenario data. These issues related to the 2041-2060 model, where it was observed that in comparing the 2021 – 2040 model and the 2041-2060 model, the annual rainfall actually increased in the 2041-2060 model for a large area of the state. This was also observed in the RCP8.5 2041-2060 model rainfall but to a lesser extent.

In following up this issue with Leanne Webb, CSIRO, the team was advised the observations were likely to be variability in the model response, where there will be wetter and drier decades, though with an overall trend to drying.

Direct Climate Stressors

The direct climate stressors to be considered.

- Mean Daily Maximum Temperatures (Tmax) for each season
- Mean Daily Rainfall (Precipitation) for each season
- Wind Speed (m/sec)

Climate Change Time Frames

The base line climate data for the CMIP5 climate projections was based on average climate variables for the period 1961–1990. For the purposes of this project the baseline year was identified as 1990. Hence, the 2090 time period was viewed to represent the 100 year timeframe scenario.

The years at which potential impacts have been assessed in this project based on emission scenario information provided in the CMIP5 climate model results from CSIRO were:

- 2030 (40 years from the baseline year)
- 2050 (60 years from the baseline year)
- 2070 (80 years from the baseline year)
- 2090 (100 years from the baseline year)

Marine Related Exposures

For the purposes of identifying likely climate change stressors on rocky reefs, rock shores, mud flats and sea grass areas, the Victorian coast was divided into the following four key sectors identified by Klemke and Arundel (editors, 2013):

- Western Coast
- Central Coast
- Eastern Coast
- Embayments (that includes Port Phillip Bay, Westernport, and Corner Inlet, and other inlets)

Based on the work by Klemke and Arundel (editors, 2013) the likely indirect climate stressors in relation to the additional coastal/marine assets were identified to be:

- Sea Surface Temperature
- Run-off Volume
- Waves

The anticipated change in these three indirect climate stressors over time is presented in Table 28.

Table 28. Anticipated change for in three indirect climate stressors over time for key coastal areas.

Source: Klemke and Arundel (editors, 2013)

Process/Parameter		Western			Central			Embayments			Eastern		
		2030	2070	2100	2030	2070	2100	2030	2070	2100	2030	2070	2100
Sea Surface Temperature	deg. C	↑<0.5 -1	↑<1 - 2	↑<1.5 - 3	↑<0.5 - 1	↑<1 - 3	↑<1.5 - 3	Potentially significant increases expected			↑<1	↑<3	↑>3
Waves		Potential increase in wave energy due to postive trend in the Southern Annular Mode			Potential increase in wave energy due to postive trend in the Southern Annular Mode			Potential reductiond in wave energy due to reduced frequency of strong westerly wind conditions			No significant change expected		
Run-off Volume	%	↓15-22%	↓27-36%		↓12-18%	↓23-31%		↓12-14	↓23-26%		↓8-14%	↓15-26%	

Summary of anticipated change in indirect climate stressors used to assign Potential Impact

Indirect Climate Stressor	Western Coast	Central Coast	Embayments	Eastern Coast
Sea Surface Temperature	Low	Low	High	Medium
Waves	Medium	Medium	Very Low	Low
Run-off Volume	High	Medium	Low	Low

(Map and top section sourced from: Klemke and Arundel, editors, 2013)

Appendix 4: The Coast as an Asset

The Coast as an Asset

Victoria has a long and varied coast, mostly coast consisting of open coastal regions. There are also a number of bays, inlets, lagoons, estuaries and other suchlike landforms found along coastal Victoria. Open coastal regions are principally a mixture of rocky and sandy coasts, where inlet areas also can include muddy (mangroves, wetlands, tidal flats), estuarine and other soft shoreline landforms as well as rocky and sandy shores.

A summary of the coastline in relation to these coastal landform types and features is presented in Table 29.

Portions of the coastline have also had significant impacts from human intervention over time, including coastal and bay settlements and other engineered structures including breakwaters, groynes and dredged areas.

Table 29. Summary of the coastline in relation to these coastal landform types and features

	Hard Rock	Soft Rock	Sandy Shores w. soft sediment backdrop	Sandy Coast w. bedrock and hard rock backdrop	Muddy Shores
Indicative Length (km)	510	130	690	490	500
Indicative Proportion (%)	22%	6%	30%	21%	22%

Source: Adapted from DCC (2009). Australian Government 2009. *Climate Change Risks to Australia's Coast: A First Pass National Assessment.* Department of Climate Change: Canberra.

The overall study area for this project was the coastal region of Victoria, including all bays and inlets along the coast as well as any engineered or human impacted areas. As an overall area this includes all natural and man-made structures either on or in the shore/coast line (i.e. piers, tidal flats, rock platforms) or setback a distance from but still related to the coast (i.e. property structures or coastal dune and barrier formations).

A key consideration to be addressed in the initial workshop has been the definition of the coast and hence spatial extent of the area to be assessed. A possible definition based on elevation (based on coastal influence) and sea water depth has been considered.

The issue of water catchments impacting the coast has also been considered and potentially used in the assessment.

Appendix 5: Coast Asset Datasets and Sources

Data Set References

Seagrass Mapping:

Roob R, Ball D (1997) Seagrass: Gippsland Lakes. Marine and Freshwater Resources Institute Report to Fisheries Victoria. Queenscliff.

Blake S, Ball D (2001) Victorian Marine Habitat Database: Seagrass Mapping of Port Phillip Bay. Marine and Freshwater Resources Institute. Queenscliff.

Blake S, Ball D (2001) Victorian Marine Habitat Database: Seagrass Mapping of Western Port. Marine and Freshwater Resources Institute. Queenscliff.

Ball D, Parry GD, Heislers S, Blake S, Werner G, Young P, Coots A (2010) Victorian multi-regional seagrass health assessment 2004-07. Fisheries Victoria Technical Report No. 66, Department of Primary Industries Victoria. Queenscliff.

Ball D (2013) Mud Island Seagrass and Coastline Mapping 2011-12. Parks Victoria Technical Series No. 86. Parks Victoria. Melbourne.

Ball D, Soto-Berelov M, Young P (2014) Historical seagrass mapping in Port Phillip Bay. Journal of Coastal conservation 18, 257-272.

French T, Monk J, Ierodiaconou D, Pope A, Ball D (2014) Yaringa and French Islandd Marine National Park Habitat Mapping. Parks Victoria Technical Series No. 96. Parks Victoria. Melbourne.
Flynn A, Edmunds M, Ierodiaconou D, Ferns LW (2017) Combined biotope classification scheme (CBiCS) of long-term subtidal reef monitoring data from across the Victorian coast, 1998 to 2015. Unpublished Work by Fathom Pacific, Australian Marine Ecology, Deakin University and Department of Environment, Land, Water and Planning. Melbourne.

Flynn A, Edmunds M, Ierodiaconou D, Ferns LW (2016) Combined biotope classification scheme (CBiCS) of Port Phillip Bay lidar ground truthing video, stills and other available imagery and data. Melbourne. Unpublished Work by Fathom Pacific, Australian Marine Ecology, Deakin University and Department of Environment, Land, Water and Planning.

Flynn A, Edmunds M, Ierodiaconou D, Rattray A, Ferns LW (2017) Combined biotope classification scheme (CBiCS) of Western Port lidar ground truthing video and other available imagery and data. Unpublished Work by Fathom Pacific, Australian Marine Ecology, Deakin University and Department of Environment, Land, Water and Planning. Melbourne.

SUBSTRATA100 layer (open coast)

Ferns LW (1999) Environmental inventory of Victoria's marine ecosystems - stage 4 (part 1) - Physical classification of soft benthic habitats of the open coast. Department of Natural Resources and Environment. East Melbourne.

Ferns LW and Hough, D. (Eds.) Environmental Inventory of Victoria's Marine Ecosystems Stage 3 (Volume 2) (2000). Parks, Flora and Fauna Division, Department of Natural Resources and Environment. East Melbourne. Australia

Bathymetry:

DELWP (2016). Victorian Coastal Nearshore Bathymetry 20m resolution DEM 5m Contours. DELWP, Victoria. [online: https://www.data.vic.gov.au/data/dataset/victorian-coastal-nearshore-bathymetry-20m-resolution-dem-5m-contours]

Sediment Compartment Application:

NCCARF, 2016: Datasets Guidance 1: Shoreline Explorer. Present-day coastal sensitivity to flooding and erosion. CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

Geoscience Australia. Australian Coastal Sediment Compartments. Geoscience Australia. [online: http://data.gov.au/dataset/149b89a6-69cf-451a-87f3-1a52d1b080c1]

Wave Modelling:

Durrant, Thomas; Hemer, Mark; Trenham, Claire; Greenslade, Diana (2013): CAWCR Wave Hindcast 1979-2010. v7. CSIRO. Data Collection.http://doi.org/10.4225/08/523168703DCC5

Input	Dataset	Description
Exposure		
Coastal Type **Orientation** **Fetch**	• SmartLine • SmartLine_2008 • SV_SmartLine_2008	Primary input for the coastline.
Wave Height **Wave Energy**	• CAWCR Wave Hidcast 1979-2010	Database collection for various facets of wave related data.
Bathymetric Profile	• Victorian Coastal Nearshore Bathymetry 20m resolution DEM 5m Contours	5m contour intervals derived from 20m resolution bathymetry for nearshore Victorian Coast
Sensitivity		
Erodibility	• SV_SmartLine_2008	Coastline dataset with erodibility attributes
Compartment Sensitivity	• Australian Coastal Sediment Compartments	Secondary Compartment polygons sourced for data collection gdb. Attributed from source material on CoastAdapt
Adaptive Capacity		
Intertidal Vegetation	• CBICS_PPB_Title • CBICS_WPB_Title • Port Phillip Bay Intertidal Marine Vegetation • Western Port Intertidal Marine Vegetation • Corner Inlet Seagrass and Intertidal Marine Vegetation • Mallacoota Inlet Seagrass and Intertidal Marine Vegetation • Anderson Inlet Seagrass and Intertidal Marine Vegetation • Shallow Inlet Seagrass and Intertidal Marine Vegetation • Wingan Inlet Seagrass and Intertidal Marine Vegetation • Tamboon Inlet Seagrass and Intertidal Marine Vegetation • Sydenham Inlet Seagrass and Intertidal Marine Vegetation	See above for references
Coastal Vegetation	• Intertidal_evc_final_vg94	Based of Boon studies
Engineered Structures	• VMHYDRO_WATER_STRUCTURES • BSW_Coastal_Assets_Database • CPS_GDA_94_coastal_protection_structures • VIC_Protection_Structures_Condition_Attributes	Supplied through DELWP
Reefs	• SUBSTRATA100	See above for references
Inundation Factors		
Flood 1 in 100 year	• Victoria Flood Database	Database collection for various extents of flooding across Victoria.
Coastal Acid Sulphate Soils	• Coastal Acid Sulphate Soils	Polygon extent dataset for CASS

Input	Dataset	Description
Sea Level Rise 2040	• SLR20CM_2040	
Sea Level Rise 2070	• SLR47CM_2070	
Sea Level Rise 2100	• SLR82CM_2100	
Storm Surge 2040	• SLR20CM_ST_2040	
Storm Surge 2070	• SLR47CM_ST_2070	
Storm Surge 2100	• SLR82CM_ST_2100	
	Decay	
Digital Elevation Model	• VICMAP_VMELEV_DTM20M	
Land Cover	• Victorian Land Use Information Scheme (VLUIS)	Land Cover field used.
	Assets	
Features of Interest (FOI)	• VMFEAT_FOI_POINT • VMFEAT_FOI_LINE • VMFEAT_FOI_POLYGON	
Parks and Reserves	• PLM25	
Roads	• VMTRANS_ROAD	
Heritage	• VMPLAN_PLAN_OVERLAY	
	Miscellaneous	
Sediment Compartment	• Australian Coastal Sediment Compartments	
Coastline	• SV_SmartLine_2008	
Local Government Areas	• VMADMIN_LGA_POLYGON	
Contours	• VMELEV_CONTOUR	
Bathymetry	• bathymetry_bass_strait_arc • bathymetry_port_philip_arc • bathymetry_wester_port_arc	

Appendix 6: Reference studies

Reference Studies

Author	Report Name	Report / Study Type	Year	File Type	Focus
Gitay et al	A Framework for assessing the vulnerability of wetlands to climate change	Research - Report	2011	pdf	Asset Study - RAMSAR
Menkhurst, P	A survey of colonially breeding birds on Mud Islands	Research - Report	2010	pdf	Research Report - Shorebirds
Basic & Cartwright	An Evaluation of the Flood Warning Information System	Research - Paper	2009	pdf	Research Paper - Flood Risk
Corrangamite CMA	Anglesea Estuary Rock Wall Removal – Risk Assessment	Detailed Assessment - Barwon South West	2012	pdf	
DEPI	Apollo Bay sand movement	Detailed Assessment - Barwon South West	2013	pdf	Area Assessment - Sediment
Elliot, M	Application of Geomorphic Frameworks to Sea-level Rise Impact Assessment	Research - Paper	2014	pdf	Research Report - Inundation and SLR
VCC	Assessing the value of Coastal Resources in Victoria	Departmental - VCC	2013	pdf	
VCC	Assessing the Value of the Coast to Victoria	Departmental - VCC	2007	pdf	
Abuodha & Woodroffe	Assessing Vul of coasts to C.Change - Review of Approach and Application to the Aus Coast	Research - Paper	2006	pdf	Research Paper - CVI Australia
Jenkins, G	Assessment of anthropogenic threats to priority areas in Victoria's marine environment – refined threat assessment approach	Research - Paper	2013	pdf	Research Paper - Risk Assessment
DELWP	Assessment Results - Coastal Protection Asset Database - BSW	Assessment Results	2015	xlsx	Assessment Results
DELWP	Assessment Results - LCHA Criteria & Map Use	Assessment Results	2015	folder	Assessment Results - pdf, xlsx, doc
DELWP	Assessment Results - Risks & Assessment - BSW	Assessment Results	2015	folder	Assessment Results - pdf, xlsx, doc
DELWP	Assessment Results - Risks & Assessment - Gippsland	Assessment Results	2015	folder	Assessment Results - pdf, xlsx, doc
DELWP	Assessment Results - Risks & Assessment - Port Phillip	Assessment Results	2015	folder	Assessment Results - pdf, xlsx, doc
DELWP	Assessment Results - Value - Port Phillip	Assessment Results	2015	folder	Assessment Results - pdf, xlsx, doc
DELWP	Assessment Results - Values - BSW	Assessment Results	2015	folder	Assessment Results - pdf, xlsx, doc
DELWP	Assessment Results - Values - Gippsland	Assessment Results	2015	folder	Assessment Results - pdf, xlsx, doc
Mornington Peninsula Shire Council	Balnarring Beach Foreshore Identification and Assessment of Assets on Coastal Crown Land	Detailed Assessment - Port Phillip	2015	pdf	Asset Condition Assessment
Bass Coast	Bass Coast Inundation Model Submission	Detailed Assessment - Gippsland	2014	pdf	Area Assessment - LSIO
Provis, D	Bass Coast Inundation Model Submission	Research - Report	2014	pdf	Research Report - Inundation and SLR
Bayside City Council	Bayside Climate Change Strategy Summary	Detailed Assessment - Port Phillip	2012	pdf	Detailed Assessment - Port Phillip
Unknown	Beach Restoration Monitoring Program Guideline (79-12-20)	Guides-Directions-Strategies-Plans	2000	pdf	Monitoring Study - Beaches
City of Greater Geelong	Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment	Detailed Assessment - Geelong Bellarine	2014	pdf	Area Assessment - Risks and Hazards
City of Greater Geelong	Bellarine Peninsula - Corio Bay Local Coastal Hazard Assessment - Innundation Report	Detailed Assessment - Geelong Bellarine	2016	pdf	Geelong/Ballarine Innundation Report
PV	Bellarine Safe Harbour - Baseline Assessment Summary Report	Detailed Assessment - Geelong Bellarine	2007	pdf	Risk Assessment
Glenel Shire Council	Cape Bridgewater Coastal Hazard Vulnerability Assessment	Detailed Assessment - Barwon South West	2016	pdf	Area Assessment - Risks and Hazards
Glenelg Shire Council	Cape Bridgewater Coastal Hazard Vulnerability Assessment	Detailed Assessment - Barwon South West	2016	pdf	
VCC	Changes to sandy recreational beaches on the open coast of Victoria	Departmental - VCC	2012	pdf	
Kennedy & Konlechner	Changes to sandy recreational beaches on the open coast of Victoria	Research - Report	2012	pdf	Research Report - Beaches Recreational
Sinclair & Boon	Changes to Victorian Saltmarsh from mid-19 century	Research - Paper	2012	pdf	Research Paper - Saltmarsh
Cohen et al	City of Greater Geelong & Borough of Queenscliffe Flood Adaptation Effectiveness Study	Detailed Assessment - Geelong Bellarine	2016	pdf	Geelong/Ballarine Flood Assessment Report
Cummings et al	Climate Change Adaptation Guidelines in Coastal Management and Planning	National	2012	pdf	Adaption Directional Paper

Author	Report Name	Report / Study Type	Year	File Type	Focus
Hobsons Bay City Council	Climate Change Adaptation Plan	Detailed Assessment - Port Phillip	2013	pdf	
DPIW	Climate Change and Coastal Asset Vulnerability. An audit of Tasmania's coastal assets potentially vulnerable to flooding and sea-level rise.	Interstate - Tas	2008	pdf	Coastal Asset Vulnerability
Boon et al	Climate Change impact on vegeation of Westerport Bay	Research - Paper	2012	pdf	Research Paper - Coastal Veg
Reside et al	Climate change refugia for terrestrial biodiversity	Research - Report	2013	pdf	Research Report - Terrestrial Climate Refuges
PV	Climate Change Strategic Risk Assessment	Departmental - PV	2010	pdf	Risk Assessment
Gippsland Coastal Board	Climate Change, Sea Level Rise and Coastal Subsidence along the Gippsland Coast	Detailed Assessment - Gippsland	2008	pdf	Report
VASP	Climate Resilient Communities of the Barwon South West – Phase 1	Detailed Assessment - Barwon South West	2014	pdf	Vulnerability Study
NCCARF	CoastAdapt - 1st pass risk assessment	National - CoastAdapt	2016	pdf	Risk Assessment
NCCARF	CoastAdapt - 2nd pass risk assessment	National - CoastAdapt	2016	pdf	Risk Assessment
NCCARF	CoastAdapt - 3rd pass risk assessment	National - CoastAdapt	2016	pdf	Risk Assessment
NCCARF	CoastAdapt - Risk assessment Table	National - CoastAdapt	2016	pdf	Risk Assessment
Colac Otway Shire	Coastal Action Plan - Skenes Creek to Marengo	Detailed Assessment - Barwon South West	2010	pdf	Area Assessment - Coastal Action Plan
Mcintosh	Coastal Adaptation Planning- A Case Study on Victoria, Australia	National	2012	pdf	Adaption Directional Paper
DSE	Coastal Assets Needs Analysis Report Nov 2011	Departmental - DSE	2011	pdf	Asset Study - Initial Coast Scoping
VCC	Coastal Climate Change Advisory Committee Final Report	Departmental - VCC	2010	pdf	
VCC	Coastal Climate Change Advisory Committee Response	Departmental - VCC	2012	pdf	
City of Greater Geelong	Coastal Climate Change Risk Assessment	Detailed Assessment - Geelong Bellarine	2016	pdf	Geelong/Ballarine Risk Assessment
DELWP	Coastal Climate Change Risk Assessments (Volume 1 & 2)	Departmental - DELWP	2015	pdf	Risk Assessment
Great Ocean Road Coast Committee	Coastal climate change vulnerability and adaptation - Great Ocean Road	Detailed Assessment - Barwon South West	2012	pdf	Vulnerability Study
DPIW	Coastal Flooding. Review of the use of Exceedance Statistics in Tasmania	Interstate - Tas	2008	pdf	Coastal Asset Flooding
Bird, E	Coastal Geomorphology	Research - Book	2012	pdf	Book - Coastal Geomorphic
DPIW	Coastal Hazards in Tasmania - General Information Paper	Interstate - Tas	2008	pdf	Coastal Asset Hazards
City of Greater Geelong	Coastal Inspection Mgt Area 4 - Inspections 2016.10.20	Detailed Assessment - Geelong Bellarine	2016	pdf	Local Assessement - Map
DELWP	Coastal Management Guideline: Monitoring Sandy Coasts in South West Victoria	Guides-Directions-Strategies-Plans	2015	pdf	Monitoring Study - Beaches
Crist et al	Coastal Planning Interoperating toolkits	Research - Paper	2013	pdf	Research Paper - Tools
DSE	Coastal Protection Assets Condition Assessment Report	Departmental - DSE	2011	pdf	Asset Study - Engineered Structures
DPIW	Coastal Risk Management Plan - Template, Guidelines and Case Study	Interstate - Tas	2009	pdf	Coastal Asset Vulnerability / Risk Management
VCC	Coastal Spaces	Departmental - VCC	2006	pdf	
VCC	Coastal Spaces Inception Report	Departmental - VCC	2005	pdf	
Great Ocean Road Coast Committee	Coastal User Transport Strategy	Detailed Assessment - Barwon South West	2015	pdf	
University of Wollongong	Coastal Vulnerability and Adaptation Assessment	Research - Report: Vulnerability	2008	pdf	Research Report
Nguyen, T	Coastal vulnerability assessment- a case study in Kien Giang	Research - Paper	2015	pdf	Research Paper - Vulnerability
Western Coastal Board	Decision Support Framework for CCP Coastal Adaptation	Detailed Assessment - Barwon South West	2012	pdf	
DELWP	Definition of the Coast	Departmental - DELWP	2012	doc	Snippet of Depatmental Report
VCC	Derivation of Victorian Sea-Level Planning Allowances	Departmental - VCC	2013	pdf	

Author	Report Name	Report / Study Type	Year	File Type	Focus
Gornitz, V.M et al	Development of a Coastal Risk Assessment Database. Vulnerability to SLR in the US SE	Research - Paper	1994	pdf	Research Paper - CVI
DPI	Digital capture of coastal protection assets	Departmental - DPI	2012	pdf	Asset Study - Engineered Structures
Potts et al	Do marine protected areas deliver flows of ecosystems services to support human welfare?	Research - Paper	2013	pdf	Research Paper
Mariani et al	East Coast Study Project – National Geomorphic Framework for the Management and Prediction of Coastal Erosion	Research - Paper	2013	pdf	Hazard Assessment
Sousa et al	Ecosystem services provided by a complex coastal region: challenges of classification and mapping	Research - Paper	2016	pdf	Research Paper
VCC	Eemerging scientific issues on Victoria's coast	Departmental - VCC	2011	pdf	
Melbourne Water	Estimates of sediment toxicants in Western Port	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
DSE	Estuarine wetland vegetation mapping, Glenelg Hopkins CMA	Departmental - DSE	2008	pdf	Asset Study - Estuarine
Hansen et al	Fish-eating birds in Western Port: long-term trends	Research - Report	2011	pdf	Research Report
Kinsela et al	Flexible approach for forecasting change on wave dominated beaches	Research - Paper	2016	pdf	Research Paper - Beaches
Basic, F	Geographic visualisation tools for communicating flood risks to the public	Research - Paper: Thesis	2009	pdf	Research Paper - Flood Risk
WA DOP	Geology, Geomorphology and Vulnerability of the Pilbara Coast, in the Shires of Ashburton, East Pilbara and Roebourne, and the Town of Port Hedland, Western Australia	Interstate - WA	2013	pdf	WA - Technical Report
Gippsland Coastal Board	Gippsland Draft Regional Coastal Plan	Guides-Directions-Strategies-Plans	2017	pdf	Management Plan
DEPI	Gippsland Lakes/90 Mile Beach Local Coastal Hazard Assessment Project	Detailed Assessment - Gippsland	2014	pdf	Area Assessment - Risks and Hazards
Gippsland Coastal Board	Gippsland State of the Coast Update	Detailed Assessment - Gippsland	2013	pdf	Area Assessment
Glenelg Shire	Glenelg Environment Strategy	Guides-Directions-Strategies-Plans	2016	pdf	Strategy Document
Glenelg Hopkins CMA	Glenelg Hopkins CMA Climate Change Strategy	Guides-Directions-Strategies-Plans	2016	pdf	Strategy Document
Spencer et al	Global coastal wetland change under sea-level rise and related stresses. The DIVA Wetland Change Model	Research - Paper	2016	pdf	Research Paper - Saltmarsh & Wetlands
Great Ocean Road Coast Committee	Great Ocean Road Coast Survey Report	Detailed Assessment - Barwon South West	2015	pdf	
Great Ocean Road Coast Committee	Great Ocean Road Coastal Management Plan	Detailed Assessment - Barwon South West	2013	pdf	
NSW Office of Environment and Heritage	Guide to Climate Change Risk Assessment for NSW Local Government	Interstate - NSW	2011	pdf	Risk Assessment
DSE	Guidelines for Coastal Catchment Management Authorities	Departmental - DSE	2012	pdf	Assessing development in relation to sea level rise
DPIW	Historical and Projected Sea-Level Extremes for Hobart and Burnie, Tasmania	Interstate - Tas	2008	pdf	Coastal Asset Vulnerability
Mornington Peninsula Shire Council	Identification and Assessment of Assets on Coastal Crown Land	Detailed Assessment - Port Phillip	2015	pdf	Risk Assessment
James et al	Identifying climate refuges for freshwater biodiversity across Australia	Research - Report	2013	pdf	Research Report - Freshwater Climate Refuges
DELWP	Identifying Significant Values	Departmental - DELWP	2017	doc	Snippet of Depatmental Report
Cechet, R. et al.,	Impacts of Climate Change on Human Settlements and Other Nationally Significant Infrastructure in the Coastal Zone	National	2012	pdf	1st Pass Risk Assessment
Hansen et al	Improving our understanding of Waterbirds in Western Port	Research - Paper	2011	pdf	Research Paper - Shorebirds
Sharples, C	Indicative Mapping of Tasmanian Coastal Geomorphic Vulnerability to Sea-Level Rise Using a GIS Line Map of Coastal Geomorphic Attributes	Interstate - Tas - Research Paper	2006	pdf	Research Paper - Coastal Geo Vulnerability
Nguyen et a	Indicator-based assessment of climate-change impacts on coasts: A review of concepts, methodological approaches and vulnerability indices	Research - Paper	2016	pdf	Research Paper
Giardino et al	Innovative Approaches and Tools for Erosion Control and Coastline Management	Research - Paper	2013	pdf	Research Paper
Dawson et al	Integrated analysis of risks of coastal flooding and cliff erosion under scenarios of long term change	Research - Paper	2010	pdf	Research Paper

Author	Report Name	Report / Study Type	Year	File Type	Focus
Rogers et al	Local movements of shorebirds and high-resolution mapping of shorebird habitat in the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site	Research - Paper	2010	pdf	Research Paper - Wetlands
Hansen et al	Long-term declines in multiple waterbird species in a tidal embayment, south-east Australia	Research - Paper	2015	pdf	Research Paper - Shorebirds
DELWP	Lonsdale Bight Investigations Review and Options	Detailed Assessment - Geelong Bellarine	2017	pdf	Area Assessment - Risks and Hazards
DSE	Managing coastal crown land for public value	Departmental - DSE	2012	pdf	
DELWP	Managing coastal hazards and the coastal impacts of climate change	Departmental - DELWP	2015	pdf	
Melbourne Water	Mangrove planting in Western Port	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
Melbourne Water	Mangrove research in Western Port	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
Boon et al	Mangroves and Costal Saltmarshes of Victoria	Research - Paper	2011	folder	Research Paper - Saltmarsh & Wetlands
Fairbank & Jakeways	Mapping Coastal Evolution and Risks in a Changing Climate - A Training Pack	Guides-Directions-Strategies-Plans	2006	pdf	Guide Report
DELWP	Marine and Coastal Ecosystem Accounting: Port Phillip Bay	Departmental - DELWP	2016	pdf	Asset Study - Bays
DSE	Marine Assets Folder - Ecological descriptions of the significant marine environmental assets of Victoria	Departmental - DSE	2012	folder	Asset Study - Marine
KDS	Marine Biotype Assessment	Detailed Assessment	2016	pdf	Marine Biotype Assessment
Victorian Environmental Assessment Council	Marine Investigation Draft Proposals Paper	Departmental	2013	pdf	Asset Study - Marine
Torresan, S. et al.,	Methods for coastal risk assess climate change	Research - Paper	2016	pdf	Research Paper
Iwamura et al	Migratory connectivity and habitat bottlenecks for sea level rise	Research - Paper	2013	pdf	Research Paper
Alves et al	Modelling Coastal Vulnerabilities – Tool for Decision Support System at Inter-municipality Level	Research - Paper	2011	pdf	Research Paper - Vulnerability
Melbourne Water	Modelling hydrodynamics in Western Port	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
Rogers et al	Modelling wetland surface dynamics-application forecasting effects of sea level rise	Research - Paper	2012	pdf	Research Paper - Wetlands
Glenelg Shire Council	Narrawong Coastal Engineering Study	Detailed Assessment - Barwon South West	2011	pdf	Detailed Local Risk and Engineering Assessment
DSE	Natural Coastal Assets Methodology: Identifying and valuing natural coastal assets	Departmental - DSE	2012	pdf	Natural Assets
NCCARF	NCCARF - Local scale assessment	National - NCCARF	2012	pdf	Risk Assessment
NCCARF	NCCARF - Using CCADS (CoastAdapt)	National - NCCARF	2012	pdf	Risk Assessment
Woodroffe et al	NCCARF - Woodroffe, 2012: Approaches risk assessment coastal	National - NCCARF	2012	pdf	Risk Assessment
NSW Marine Estate	New South Wales Marine Estate Threat and Risk Assessment Report	Interstate - NSW	2016	pdf	Risk Assessment
NSW Marine Estate	New South Wales Marine Estate Threat and Risk Assessment Report - Glossary	Interstate - NSW	2016	pdf	Risk Assessment
Millar & Rosengren	Northern Bellarine Coastal Geomorphology	Research - Report	2017	pdf	Geomorphology Paper
Spatial Vision	NRM Climate Final Report - Impact Assessment	National	2014	pdf	Impact Assessment
Melbourne Water	Nutrient process on tidal flats in Western Port Report - Sediment toxicants in Western Port and major tributaries	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
City of Greater Geelong	Our Coast Coastal Inundation Options Report	Detailed Assessment - Geelong Bellarine	2016	pdf	Geelong/Ballarine Assessment Report
GA	OzCoast - Australian Online Costal Information	National - GA	2016	html	Coastal Website
Phillip Island Nature Park	Phillip Island Nature Parks Coastal Process Study	Detailed Assessment - Port Phillip	2014	pdf	
Phillip Island Nature Park	Phillip Island South and North Coast Key Area Plan	Detailed Assessment - Port Phillip	2014	pdf	
Phillip Island Nature Park	Phillip Island South and North Coast Key Area Plan - Inspiring Places	Detailed Assessment - Port Phillip	2014	pdf	
Melbourne Water	Planning for sea level rise	Detailed Assessment - Port Phillip	2015	pdf	
Melbourne Water	Planning for sea level rise. Assessing development in areas prone to tidal inundation from sea level rise in the Port Phillip and Westernport Region	Departmental - Melbourne Water	2012	pdf	
VCC	Population and Settlement along the Victorian Coast	Departmental - VCC	2013	pdf	

Author	Report Name	Report / Study Type	Year	File Type	Focus
UNSW	Port Fairy Coastal Hazard Assessment	Detailed Assessment - Barwon South West	2013	pdf	Area Assessment - Risks and Hazards
MAV	Port Phillip Bay Coastal Adaptation Pathways Project	Detailed Assessment - Port Phillip	2012	pdf	Area Assessment - Coastal Climate Adaptation
DELWP	**Port Phillip Bay Environmental Management Plan**	Detailed Assessment - Port Phillip	2016	pdf	Area Assessment - Risks
Melbourne Water	Port Phillip Bay Local Coastal Hazard Assessment	Detailed Assessment - Port Phillip	2016	pdf	Area Assessment - Risks and Hazards
Association of Bayside Municipalities	Port Phillip Bay Sea Level	Detailed Assessment - Port Phillip	2015	pdf	SLR Assessment
Association of Bayside Municipalities	Port Phillip Bay Wave Climate	Detailed Assessment - Port Phillip	2015	pdf	Wave Assessment
City of Port Phillip	Port Phillip Bay: Regional Coastal Adaptation Framework	Detailed Assessment - Port Phillip	2015	pdf	Area Assessment - Adaptation
DPI	Port Phillip Bay Environmental Data Review Marine Biophysical Assessment of Climate Change	Detailed Assessment - Port Phillip	2011	pdf	Area Assessment - Biophysical Assets
DEPI	Portalnd Coastal Stability Report	Detailed Assessment - Barwon South West	2013	pdf	
Glenelg Shire Council	Portland - Coastal Spaces- Inundation and Erosion- Coastal Engineering Study	Detailed Assessment - Barwon South West	2010	pdf	Detailed Local Risk and Engineering Assessment
DELWP	Portsea Front Beach Remediation	Detailed Assessment - Port Phillip	2016	pdf	
DELWP	Portsea Front BeachWave Modelling and Monitoring Investigation	Detailed Assessment - Port Phillip	2016	pdf	
Boon, P	Presentation-Mangroves & Saltmarsh	Research - Paper	2012	pdf	Research Paper - EVC Mapping
DELWP	**Prioritising Environmental Issues for Development of the New Port Phillip Bay Environmental Management Plan**	Detailed Assessment - Port Phillip	2016	pdf	Area Assessment - Risks
DELWP	Priority locations for detailed coastal hazard mapping and adaptation planning along the Victorian coastline	Departmental - DELWP	2015	pdf	Hazard Assessment
Borough of Queenscliffe	Queenscliffe_Coastal_Management_Plan_2006	Detailed Assessment - Geelong Bellarine	2006	pdf	Area Assessment
DSE	Review of Victorian Seagrass Research, with emphasis on Port Phillip Bay	Departmental - DSE	2009	pdf	Asset Study - Seagrass
PV	Risk Assessment and the concept of Ecosystem	Departmental - PV	2004	pdf	Risk Assessment
San Remo Foreshore Reserve Committee	San Remo Management Plan	Detailed Assessment - Port Phillip	2010	pdf	
DELWP	Sandringham Sand Management Scoping Study	Detailed Assessment - Port Phillip	2016	pdf	
Melbourne Water	Seagrass - protection and recovery	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
DPI	Seagrass and Reef Program for Port Phillip Bay: Temperate Reefs Literature Review	Departmental - DPI	2010	pdf	Asset Study - Seagrass
DPIW	Sea-Level Extremes In Tasmania Summary and Practical Guide for Planners and Managers	Interstate - Tas	2008	pdf	Coastal Asset Vulnerability
MAV	SECAP - Spatially Enabling Coastal Assets Project	Departmental	2011	folder	Asset Study
Melbourne Water	Sediment - inputs, interactions, remote sensing	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
Brooks & Spencer	Shoreline retreat and sediment release in response to accelerating sea level rise	Research - Paper	2012	pdf	Research Paper - Sedimentation and Erosion
Commissioner for Environmental Sustainability	State of the Bays 2016	Departmental	2016	pdf	Asset Study - Bays
Association of Bayside Municipalities	Strategic Directions	Detailed Assessment - Port Phillip	2012	pdf	Detailed Assessment - Port Phillip
Boon, P	Study reveals threats to Victoria's mangroves and coastal saltmarsh	Research - Paper	2012	pdf	Research Paper - Coastal Veg
Crist et al	Supporting cross-sector, cross-domain planning through interoperating toolkits	Research - Paper	2013	pdf	Research Paper
Cardno	Techniques for Sand Monitoring for Port Phillip Beaches	Guides-Directions-Strategies-Plans	2014	pdf	Monitoring Study - Beaches

Author	Report Name	Report / Study Type	Year	File Type	Focus
Smyth, C	The Coast is Unclear - An Uncertain Future for Nature Along the Victorian Coasts	Research - Report	2014	pdf	Research Report
Saintilan & Rogers	The Declining Saltmarsh Resource	Research - Paper	2002	pdf	Research Paper - Saltmarsh
NCCARF	The Economic Value of Natural and Built Coastal Assets (Vol 1 & 2)	National - NCCARF	2011	pdf	Economic Assessment
CSIRO	The Effect of Climate Change on Extreme Sea Levels in Port Phillip Bay	Detailed Assessment - Port Phillip	2009	pdf	Area Assessment - Stressors
Bayside Bellarine Foreshore Committee	The Northern Bellarine Foreshore Plan	Detailed Assessment - Geelong Bellarine	2012	pdf	Management Plan
DSE	The potential impacts of climate change on the Phillip Island Little Penguin colony - regional economic impacts	Detailed Assessment - Port Phillip	2009	pdf	
Shaw et al	The Sensitivity of the Coasts of Canada to Sea Level Rise.	Research - Paper	1998	pdf	Research Paper - CVI - Sensitivity
Saintilan & Rogers	The significance and vulnerability of Australian saltmarshes: implications for management in a changing climate	Research - Paper	2013	pdf	Research Paper - Saltmarsh
Zanuttigh, B	Theseus - Innovative technologies for safer European coasts in a changing climate	Guides-Directions-Strategies-Plans	2014	pdf	Toolkit/Methodology
DSE	Tooradin Foreshore Reserve Coastal Processes Study	Detailed Assessment - Port Phillip	2008	pdf	Detailed Local Coastal Processes Report
DELWP	Valuing and accounting for Victoria’s environment: Strategic Plan 2015-2020	Guides-Directions-Strategies-Plans	2015	pdf	Strategy Document
Rogers et al	Vegetation change and surface elevation dynamics in estuarine wetlands of southeast Australia	Research - Paper	2006	pdf	Research Paper - Wetlands
DELWP	Victoria’s Climate Change Adaptation Plan Directions Paper	Guides-Directions-Strategies-Plans	2016	pdf	Adaption Directional Paper
DSE	Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils	Departmental - DSE	2010	pdf	Stressor - CASS
DSE	Victorian Coastal Acid Sulfate Soils Strategy	Departmental - DSE	2009	pdf	Stressor - CASS
DSE	Victorian Coastal Hazard Guide	Guides-Directions-Strategies-Plans	2012	pdf	Hazard Assessment
Victorian Coastal Council	Victorian Coastal Strategy	Departmental	2014	pdf	Asset Study - Full Coast
Port of Melbourne Authority	Victorian Coastal Vulnerability Study	Detailed Assessment	1992	pdf	Detailed Assessment - Vulnerability
DELWP	Victorian Floodplain Management Strategy	Guides-Directions-Strategies-Plans	2016	pdf	Hazard Assessment
Hansen, B.	Waders in decline	Research - Paper	2011	pdf	Research Paper - Shorebirds
Melbourne Water	Water quality requirements of seagrass	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
Melbourne Water	Water quality requirements of seagrass	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
Hansen et al	Waterbird Usage of Western Port	Research - Report	2011	pdf	Research Report - Shorebirds
Melbourne Water	Waterbirds - 40 years of monitoring	Detailed Assessment - Melb Water	2013	pdf	Area Assessment
Melbourne Water	Western Port Local Coastal Hazard Assessment	Detailed Assessment - Port Phillip	2014	pdf	Area Assessment - Risks and Hazards
Melbourne Water	Western Port seagrass species - overview	Detailed Assessment - Melb Water	2013	pdf	Area Assessment

Appendix 7: Asset Classification List

Economic			
Economic infrastructure		**Property**	
2	Transport	1	Property
2.1	Road Network	1.1	Residential
	Hwy/Fwy	1.2	Commercial
	Major routes	1.3	Industry
	Roads	**Economic production**	
	Other	4	Primary Industries
2.2	Road Infrastructure	4.1	Agriculture
	Car Parks		Broadacre
	Bridges		Horticulture
	Tunnels		Pasture
2.3	Rail Network		Livestock
	Railroad		Irrigation
	Tramways	4.2	Forestry
2.4	Rail Infrastructure		Softwood
	Train Stations		Hardwood
	Tram Stops	4.3	Extractive Industries
	Depot		Oil
	Towers		Gas
2.5	Airport		Coal
	Runways	4.4	Fisheries
	Terminals		Aquaculture
	Control Towers		Small-Take
2.6	Marine and Shipping		Coastal Fishing
	Lighthouse		Boating Facilities
	Beacon	**Coastal Infrastructure**	
	Navigation Lines/Channels	5	Coastal Infrastructure
	Ferry Terminals	5.1	Engineered - Hard (Vertical)
	Port - Commercial		Seawall
	Wharf/Dock		Breakwater
3	Utility		Wharf
3.1	Electricity	5.2	Engineered - Hard (Sloping)
	Sub-Stations		Revetment
	Power Plants		Breakwater
	Wind Turbines		Boat Ramps
	Solar Installations	5.3	Engineered - Hard (Sandy Front)
	Power Poles		Revetment
	Transmission Lines	5.4	Engineered - Sand
3.2	Water		Beach Nourishment
	Treatment Plants	5.5	Engineered - Interrupted
	Sewerage Lines		Groyne
	Stormwater		Artificial Reef
	Drainage		
	Reservoirs		
	Irrigation Channels		
3.3	Oil/Gas		
	Platforms		
	Refineries		
	Gas Pipe Lines		

Social / Cultural			
Social Infrastructure		**Wellbeing**	
6	Services	7	Social/Recreational
6.1	Health	7.1	Recreational
	Hospital		Camping/Caravan Park
	Aged Care Facilities		Golf Clubs
6.2	Education		Sporting Grounds
	School Primary		Surf Life Saving Clubs
	School Secondary		Pathways/Walks/Lookouts
	University		Park Recreational Facilities

Social / Cultural			
Social Infrastructure		**Wellbeing**	
	Training College/TAFE		Sailing Clubs
	Pre-School/Kinder		Beach/Beach Access
6.3	Emergency Services		Port - Recreational (Marina)
	Fire Station - Metro/CFA		Promenade
	Police Station		Pier
	SES Station		Jetty
			Wharf
			Boat Ramp
			Boating Facilities
			Surf Breaks
			Tourism Attractions
			Tourism Info Centres
		7.2	Social / Cultural Value
			Cultural Heritage - Historical
			Cultural Heritage - Indigenous
			Wrecks
			Cemetery
			Landscape
			Geomorphological significance

Environmental			
Biodiversity and Water		**Coastline**	
8	Natural	9	Geological/Landforms
8.1	Terrestrial Features		Muddy
	Public land status		Sandy
	Vegetation types		Dunes
	Wetlands/RAMSAR		Coarse
	Estuaries		Undifferentiated Sand
	Waterways		Soft Rock
	Inlets		Hard Rock
	Deltas		Undifferentiated Rock
	Significant Flora & Fauna		Coral
	Inland Fauna Breeding Sites		Engineered
	Inland Fauna Habitat		
	Coastal Fauna Breeding Sites		
	Coastal Fauna Habitat		
	Old growth		
8.2	Marine Features		
	Parks and reserves		
	Seagrass		
	Intertidal Fauna Breeding Sites		
	Intertidal Fauna Habitat		

Appendix 8: Acronyms

Acronyms

AEP	Annual Exceedance Probability
BOM	Bureau of Meteorology
CMA	Catchment Management Authority
DELWP	Department of Environment, Land Water and Planning
EVC	ecological vegetation class
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
LCHA	Local Coastal Hazard Assessment
LGA	Local Government Area
NCCARF	National Climate Change Adaptation Research Facility
NRM	natural resource management
PCG	Project Control Group
PV	Parks Victoria
RCS	Regional Catchment Strategy
SCARP	Southern Slopes Climate Change Adaptation Research Partnership
SV	Spatial Vision
STM	Storm Surge
SLR	Sea Level Rise